HUNTSMAN
BUILDING SOLUTIONS

December 14th, 2020

Object : Under Slab Insulation / Radon Control – Heatlok Soya HFO

Energy efficiency requirements are constantly increasing in all types of buildings. Many states now require insulation below the basement slab or slab on grade. There are now also requirements to protect the occupant from soil gas like radon in National and Provincial Codes.

It is often very complicated and costly to get a perfectly sealed under slab system. Heatlok Soya HFO can provide a quick and simple solution for any under slab insulation. A solution that can be adapted easily to any shape or details of all types of construction. Heatlok Soya HFO can be sprayed directly on crushed stones or dirt to provide a perfectly sealed under slab insulation system. The concrete slab can then be poured directly on the product.

Insulation, Air Barrier and Vapour Barrier Properties

Heatlok Soya HFO is one of the most effective insulation products on the market with an R-Value of R-6 per inch. It can be applied to any thickness desired to meet the energy requirements. Due to its continuity and the fact that it is seamless, it also provides a continuous air barrier assembly under the slab and seals ~~to~~ any penetration, like plumbing pipes or others without the use of tape or sealant. It has been tested in accordance with ASTM E2178 with an air permeance result of less than 0.02 l/s-m^2 @ a 75 Pa pressure difference. It also provides a vapour barrier with a result of less than 60 ng at only 1 ¼ ''. No other vapour barrier is required, as 1 ½'' of Heatlok Soya HFO will provide sufficient resistance to vapour.

Heatlok Soya HFO provides all three necessary components for a high-performance assembly: an air barrier, a vapour barrier and insulation. This would require 3 or 4 products with other systems. Not only that, the quality of the product and its installation are superior to other systems.

* Note, if a 6-mil polyethylene is requested, it can be installed on top of the foam before pouring the concrete slab. It should <u>not</u> be installed prior to the spray foam installation.

Radon Barrier

Heatlok Soya HFO is one of the only products to have been tested for radon diffusion. Radon protection is usually provided by an air barrier material, since radon travels primarily through air. However, there can be radon diffusion through some air barrier materials. That is the reason why our product has been tested in accordance with K124/02/95 (method C of ISO/TS 11665-13) for radon diffusion. At only 1 ¼'', Heatlok Soya HFO performs 65 times better than 6 mil polyethylene for radon protection. Furthermore, the product is often installed at a thickness of 1 ½ '' to 2'' and is therefore much harder to puncture than 6 mil polyethylene when workers are walking on it during construction.

The Heatlok product has also been evaluated by a CNRPP (Radon Specialist) officer in Canada and has been characterized to outperform a poly for this application.

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A business unit of Huntsman Corporation

Compressive Strength/Durability

As mentioned before, Heatlok Soya HFO can be sprayed directly to gravel or dirt to act as insulation, air barrier, vapour barrier/vapour retarder, < 60 ng, and radon protection. To add to all of this, the product also has an excellent compressive strength for this type of application.

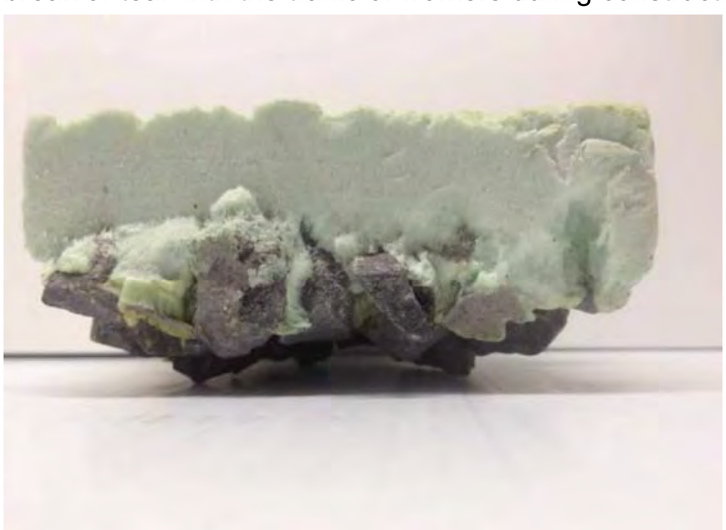
The test method used for compressive strength, ASTM D 1621 *''Standard Test Method for Compressive Properties of Rigid Cellular Plastics'',* is the same for all plastic insulation products on the market.

On the other hand, what is specific to spray polyurethane foams is that they are tested in the core of the foam only. The skin is not included and the reported density is therefore lower. The parameters of the test give conservative results, as these are laboratory conditions. Therefore, the actual overall density on site is always higher than in test conditions, which results in higher compressive performance.

The compressive strength of Heatlok Soya HFO is 24.8 PSI. As mentioned, the test results are lower than the actual installed density. This compressive strength is in the range of commonly installed products for under slab application.

ASTM D 1621 measures how much force must be exerted to compress the material by 10%. With a compressive strength of 24.8 PSI (± 3500 lbs per square foot) and considering that the average weight of concrete is 150 lbs per cubic foot, a typical 6” slab of concrete would weigh approximately 75 lbs per square foot. This is well below the structural capability of the foam.

Another advantage of this application is the fact that spray foam will penetrate the crushed stone sub-base for about ½''. The foam when applied is liquid and will penetrate the gravel (see pictures below) to seal everything. At certain areas, there will be more foam and the insulation value will therefore be increased. It makes the assembly very compact without leaving any air space between the insulation and the crushed stone subbase, thus preventing the foam from cracking when walked upon. This is one of the problems of other systems that make them weak and often break or tear with the traffic of workers during construction.



Heatlok Soya HFO is 100% in contact with its substrate making it very solid to walk on. Different thickness can be applied depending on the required R-value. 2'' as demonstrated above is a common application.

Flood Resistance

Many studies and articles have described the exceptional performance of spray foam insulation in coastal areas or hurricane and flood zones. For example, due to its excellent water-resistant properties, closed cell spray foam has received the highest rank (Class 5) by FEMA and NFIP (National Flood Insurance Program) for flood damage-resistant materials. It is also the only product accepted by FEMA for use as insulation in flood zones. It is very resistant to ground water as demonstrated by its very low water absorption characteristics and its rapid drying capability.

The Heatlok product was also studied by NRC in Canada for a period of 2 years in a below grade exterior foundation walls application without additional water proofing and it remained completely dry.

To demonstrate this, during the spring of 2017, there was a major flood in many areas of the Quebec province in Canada. Demilec was involved in a case study with one flooded home where our closed cell spray foam product had been installed years prior. There was about 4 feet of dirty water filling the entire basement. After the water was removed, only the gyprock was taken off and the basement was cleaned with power washers. After the basement was dried for about 5 days, Demilec officials inspected and tested the humidity content of the wall. Only a few small areas still showed a humidity level of more than 15%. In the end, the basement completely dried out and the foam remained in place and only the gyprock needed to be replaced. This saved a lot of time and money for the complete restoration.

Code Compliance Considerations:

2015 National Building Code Section 5.4.1., Section 9.13.4. and Section 9.25.4.2.
In addition to the depressurization system, an air barrier is also requested under slab to provide soil gas resistance. A vapour barrier is also required to provide resistance to moisture.

Under Slab Air Barrier Requirements:

As well as in Part 5, Section 9.13.4 requires an air barrier system below the slab. Heatlok Soya HFO is not only tested as an air barrier product but also as a system. We are currently transitioning our Air Barrier System testing to our Heatlok Soya HFO product.

Under Slab Vapour Barrier Requirements:

In Section 9.25.4.2. a vapour barrier is defined as a materiel that has less than 60ng when tested in accordance with ASTM E96. Heatlok Soya HFO, at a thickness of 1.25” or greater, provides a vapour barrier of less than 60ng. Typical thickness of Heatlok Soya HFO when used as a radon barrier under slabs is 1.25” or greater.

Additionally, the section requires that the vapour barrier be lapped. For a polyethylene vapour retarder this is important to ensure continuity of both the vapour retarder and the air barrier. Heatlok Soya HFO provides a monolithic continuous air and vapour retarder. Continuity of the air barrier is important because radon enters the space primarily through air gaps or cracks in the slab and around penetrations.

Under Slab Insulation Requirements:

The building code in section 9.36, requires various insulation values for slabs on grade or basement slabs. The requirements depend on your location and sometimes the heating system that you are using. The product can achieve any type of insulation requirement while protecting from radon.

For any further information, please don't hesitate to contact us.

Thank you,

Maxime Duzyk
Director of Building Science and Engineering

References

- *QAI (December 2016). Fungal Resistance Testing of Heatlok Soya HFO in accordance with ASTM C1338, Report TJ4320-2*

- *Honeywell. Closed-cell spray foam: A better building technology. Severe Weather*

- *FEMA. (August 2008). Flood damage –Resistant Materials Requirements. Technical Bulletin #2*

- *FEMA. (December 2010). Home Builder's Guide to Coastal Construction. Technical factsheet series*

- *FEMA P-499 SCHL. (1999). Basement walls that dry quickly. Research Highlights. Technical series 99-109*

- *Test Report No 124047/2018, Radon diffusion coefficient of the polyurethane foam insulation HEATLOK SOYA HFO in accordance with K124/02/95 (method C of ISO/DIS 11665-13*

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- *Building Radon Out. A step-by-step Guide on How to Build Radon-Resistant Homes. (April 2001). United States Environmental Protection Agency*

- *Radon, Reduction Guide for Canadians, Health Canada*

- *Demilec, Case Study, Basement Flooding, 2017*

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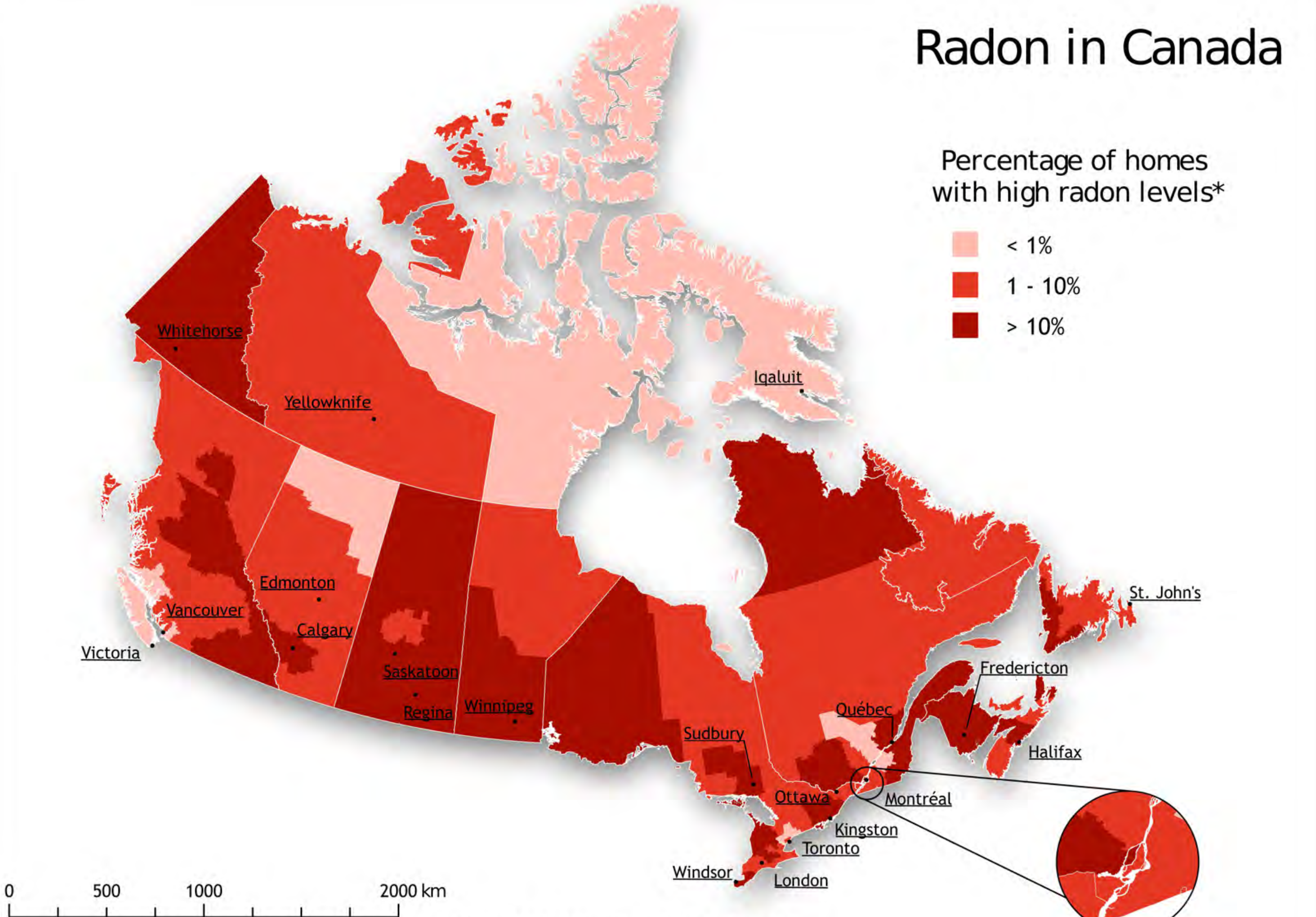
- *Building Science Corporation, Insight 101, Rebuilding Houston "Wash and Wear" (November 2017), Joseph W. Lstiburek*

- *Honeywell, Severe Weather and Closed-Cell Spray Foam : A Better Building Technology*

- *NRC-CNRC (November 2000), In-situ Performance Evaluation of Exterior Insulation Basement System `(EIBS) – Spray Polyurethane Foam Summary Report*

- *CNRPP/AARST,* http://aarst-nrpp.com/wp/

- *National Building Code of Canada 2010 and 2015*



Indoor radon data collected from the Cross-Canada Radon Survey (2011), and the Radon Thoron Survey in Canadian Metropolitan Areas (2013). Collected information is grouped by Health Region. Boundary files sourced from Statistics Canada, 2018. Map produced by Radiation Protection Bureau, Health Canada, 2019.

*A high radon level is defined as a radon level that is greater than the Health Canada guideline for indoor radon, 200 Bq/m^3.

RADON CONTROL

HEATLOK SOYA IS CERTIFIED AS A RADON CONTROL SYSTEM FOR AN UNDER SLAB APPLICATION (CCMC 14073). ITS COMPRESSIVE STRENGTH MAKES IT SUITABLE FOR DIRECT APPLICATION UNDER A CONCRETE SLAB WITHOUT DAMAGE OR DETERIORATION.

IN ONE APPLICATION, IT'S POSSIBLE TO INSULATE A COMPLETE BASEMENT FROM THE BASEMENT SLAB UP TO THE RIM JOIST, PROVIDING A TIME AND COST EFFICIENT RADON CONTROL SOLUTION.

THE CONTINUITY OF INSULATION AND PERFECT SEALING OF THE FOAM, WHICH ELIMINATE ALL GAPS AND JUNCTIONS, MAKE HEATLOK SOYA AN OPTIMAL RADON BARRIER SYSTEM COMPARED TO RIGID PANELS WITH A POLYETHYLENE MEMBRANE.

FOR 32mm OF THICKNESS, WITH A SINGLE PRODUCT, HEATLOK SOYA PROVIDES UNDER SLAB THERMAL INSULATION, A VAPOR BARRIER AS WELL AS A RADON CONTROL SYSTEM.

HEATLOK SOYA'S RADON CONTROL SOLUTION CAN BE USED IN RESIDENTIAL AND COMMERCIAL APPLICATIONS, AS WELL AS IN RETROFIT BUILDINGS.

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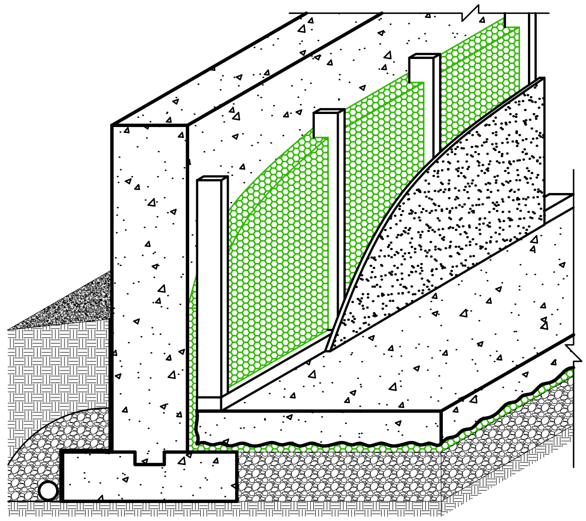
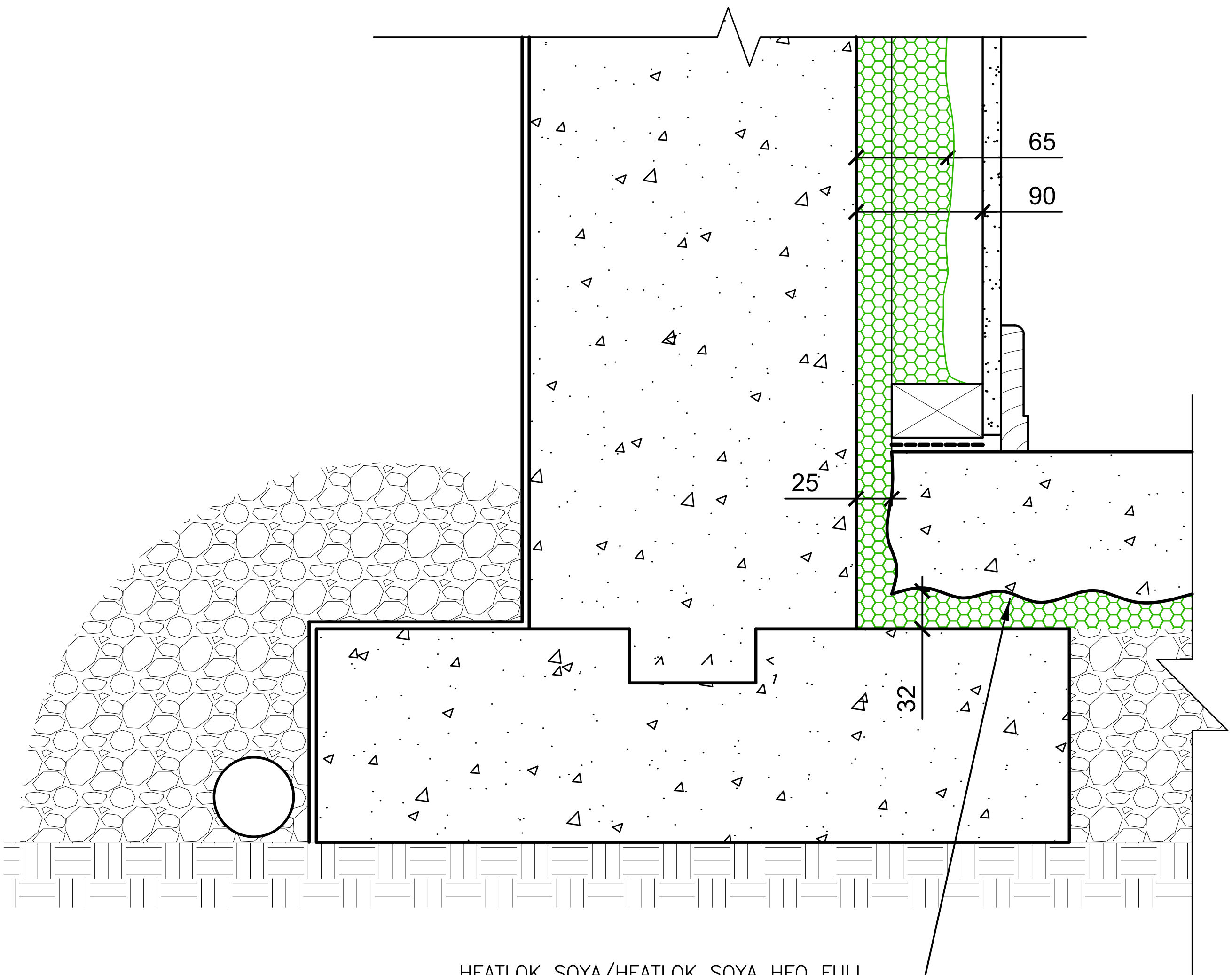
Date: 29-04-2020





TYPICAL DETAIL - 32mm UNDER SLAB
RESIDENTIAL APPLICATION

Date: 29-04-2020

Scale: 1:5

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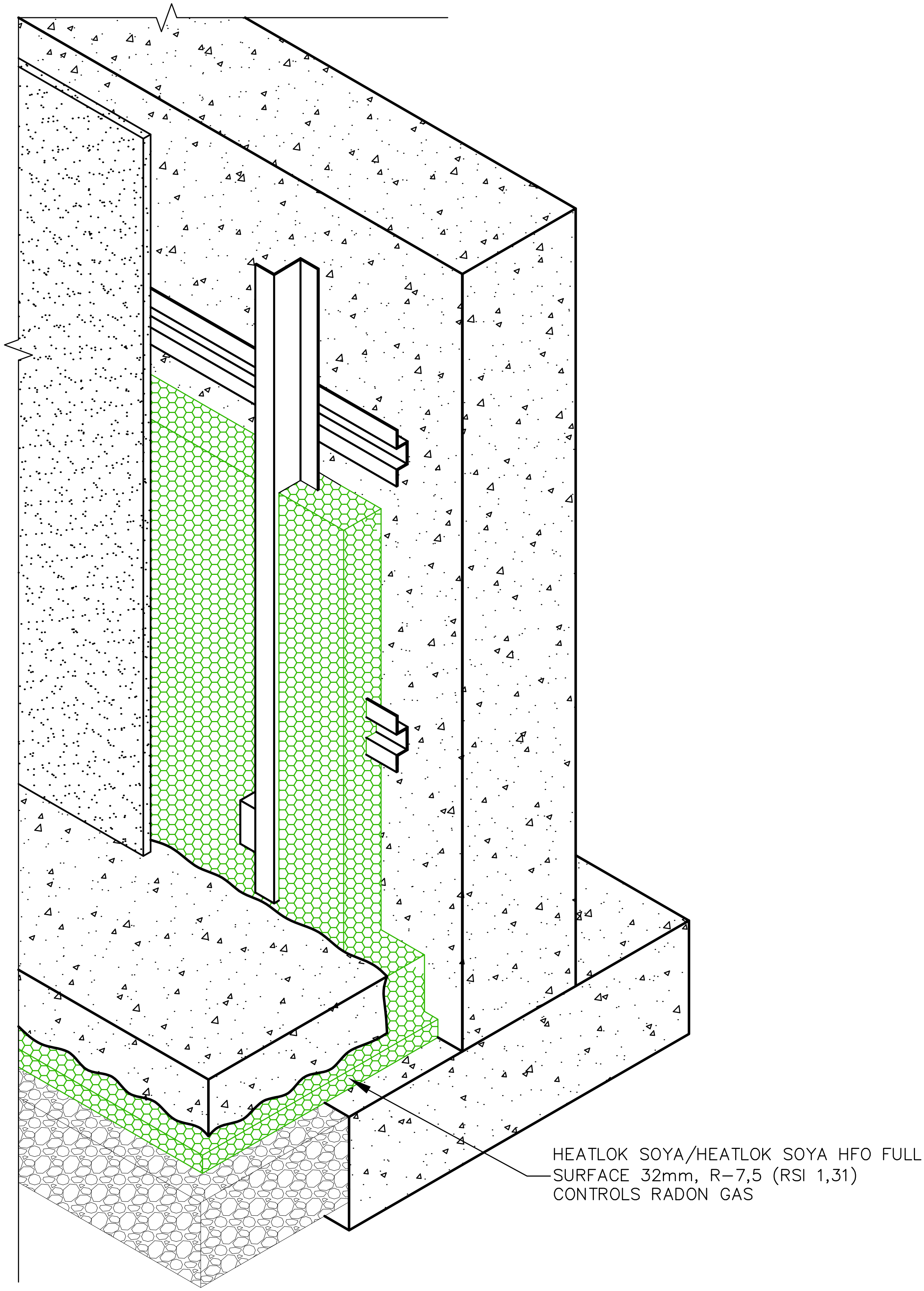
RADON SOLUTION

HEATLOK SOYA HFO



ISOMETRY - 32mm UNDER SLAB
RESIDENTIAL APPLICATION

Date: 29-04-2020

Scale: VARIABLE

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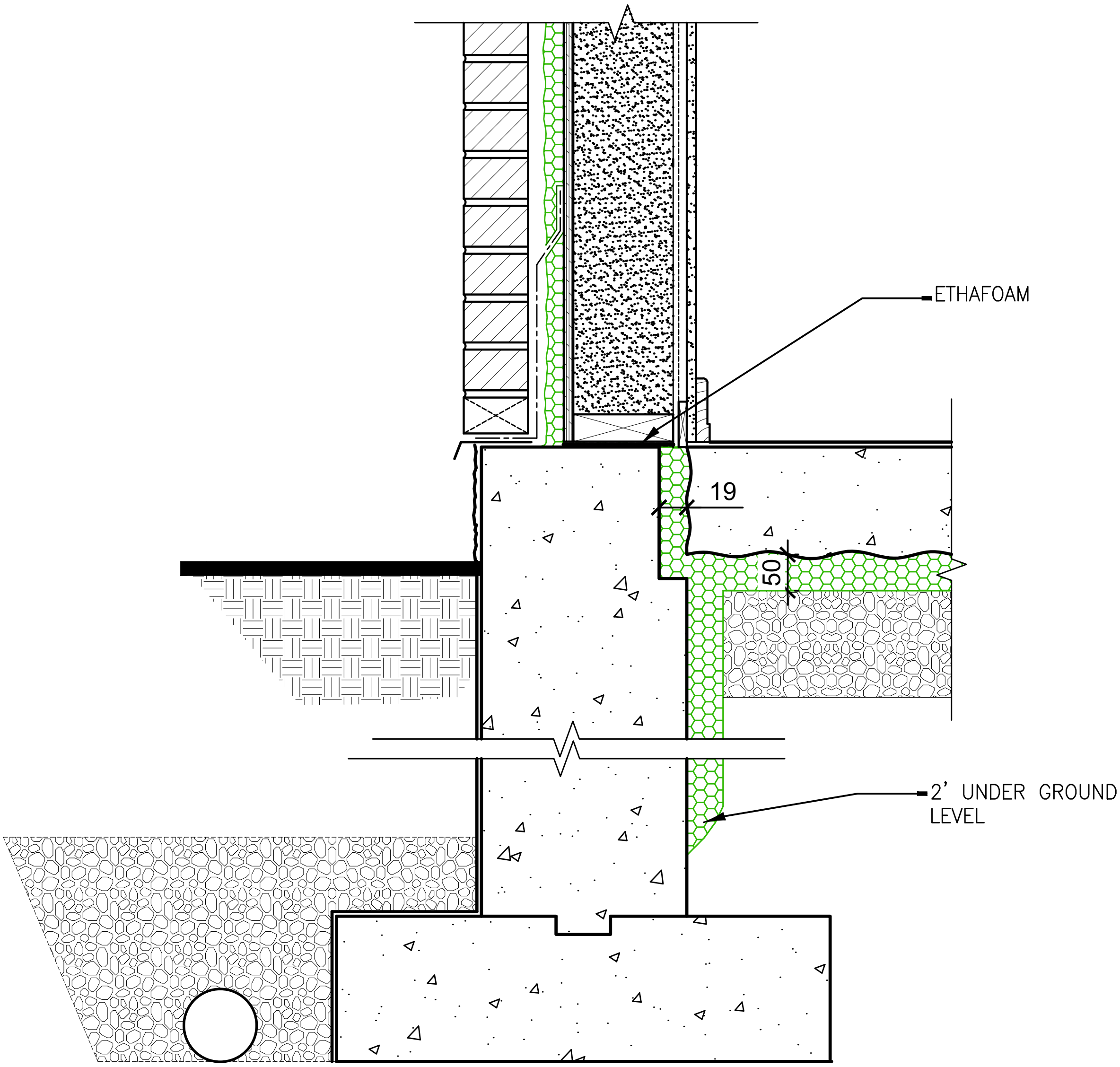
HEATLOK SOYA HFO



TYPICAL DETAIL - SLAB ON GRADE
RESIDENTIAL APPLICATION

Date: 29-04-2020

Scale: 1:10

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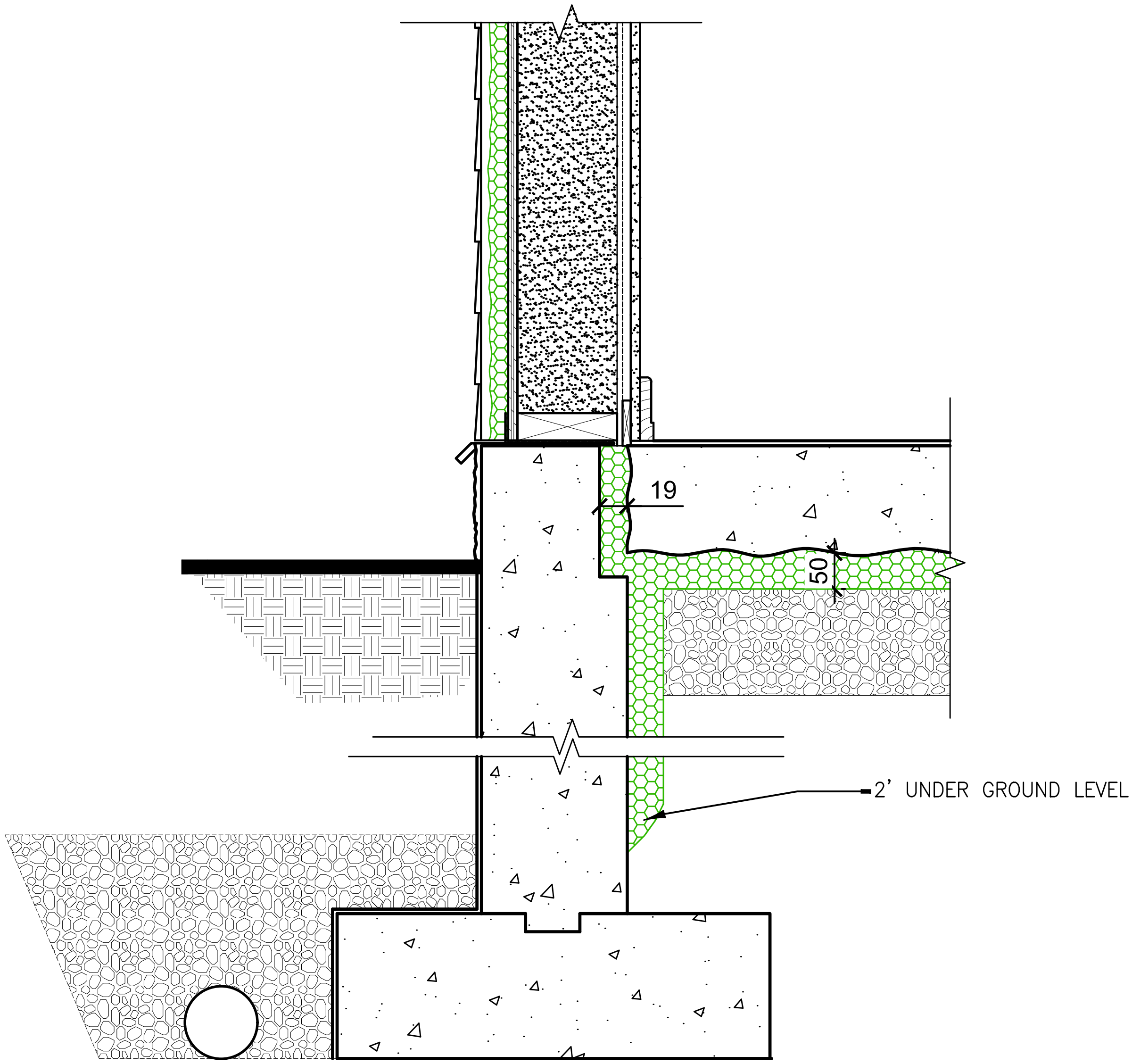
RADON SOLUTION

HEATLOK™ SOYA HFO™



TYPICAL DETAIL - SLAB ON GRADE
RESIDENTIAL APPLICATION

Date: 29-04-2020

Scale: 1:10

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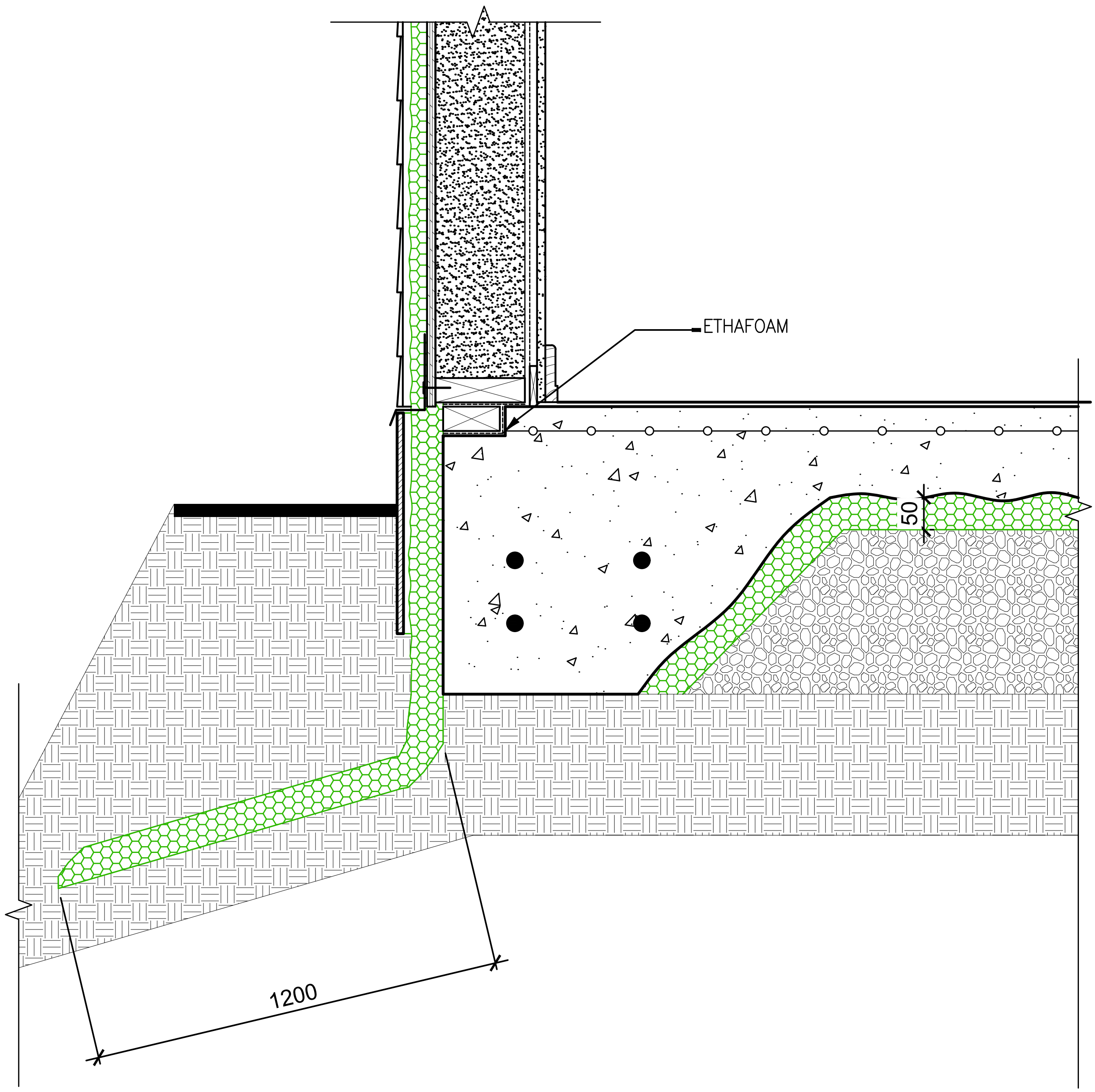
RADON SOLUTION

HEATLOK™ SOYA HFO™



TYPICAL DETAIL - SLAB ON GRADE
RESIDENTIAL APPLICATION

Date: 29-04-2020

Scale: 1:10

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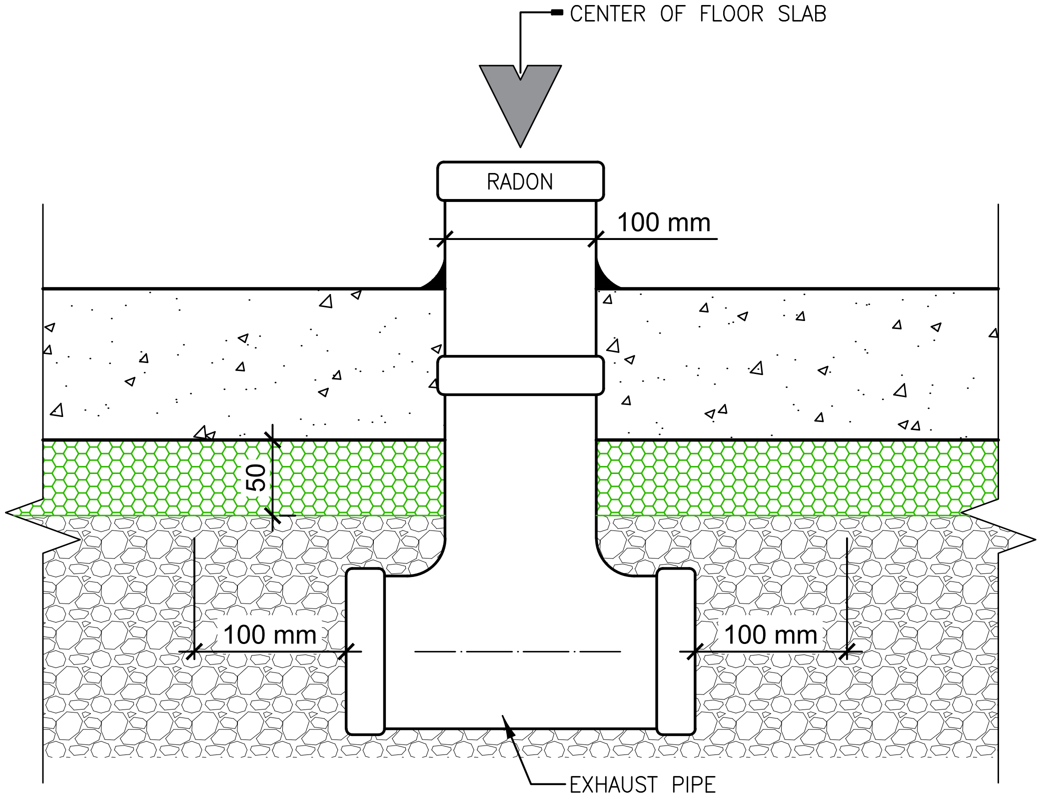
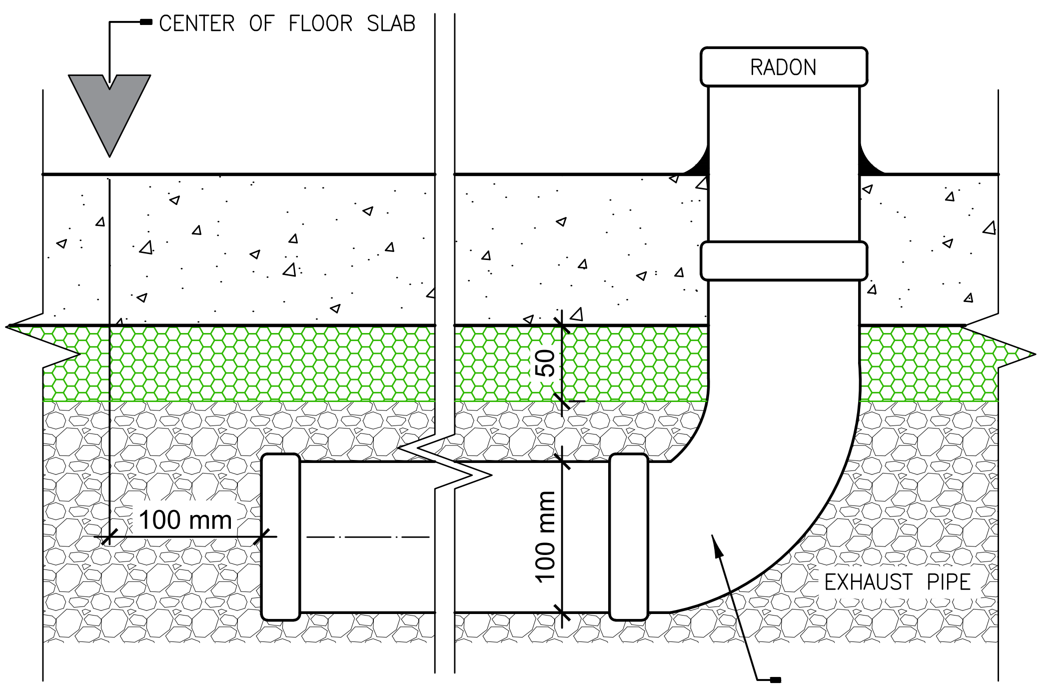
RADON SOLUTION

HEATLOK® SOYA HFO™





PERFORATED PIPE IN THE GRAVEL UNDER THE SLAB
RESIDENTIAL APPLICATION

Date: 29-04-2020

Scale: 1:5

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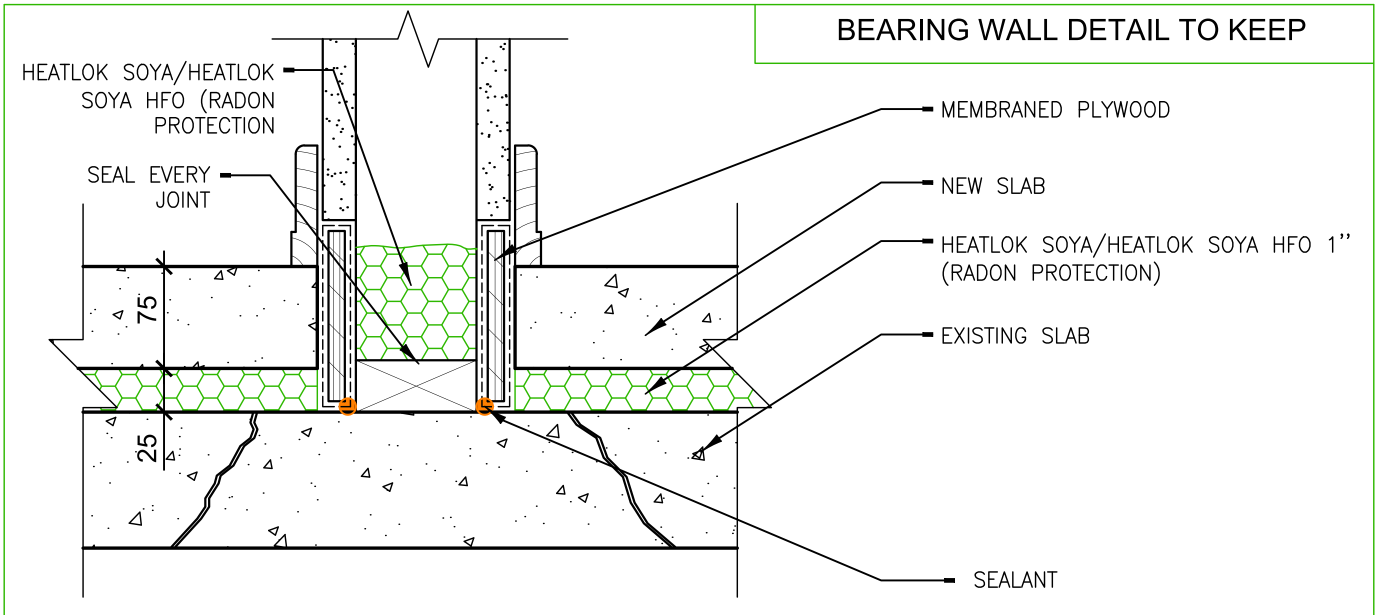
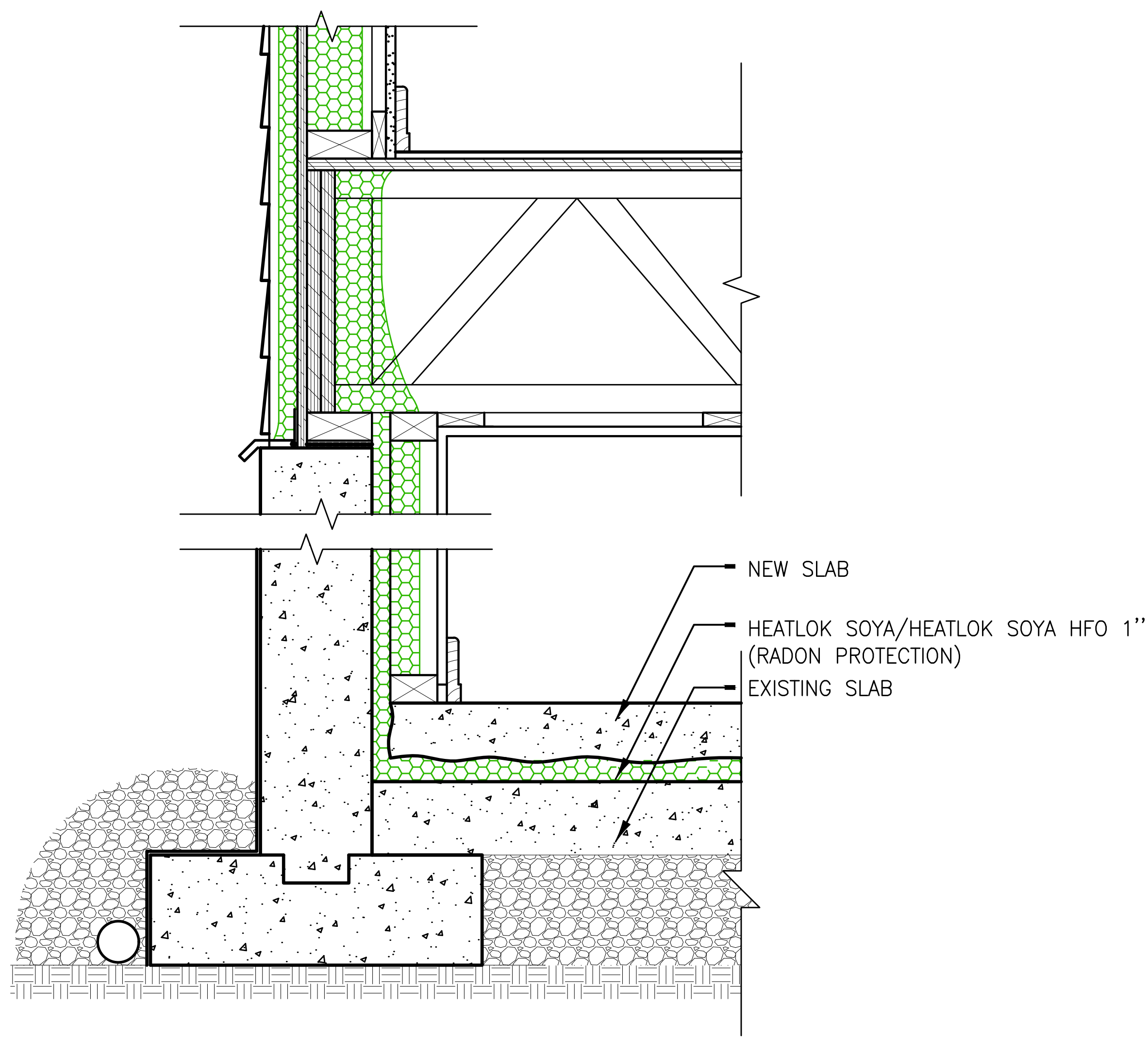
RADON SOLUTION

HEATLOK™ SOYA HFO™

BEARING WALL DETAIL TO KEEP





TYPICAL DETAIL - 1" ON EXISTING SLAB
RESIDENTIAL APPLICATION

Date: 29-04-2020

Scale: VARIABLE

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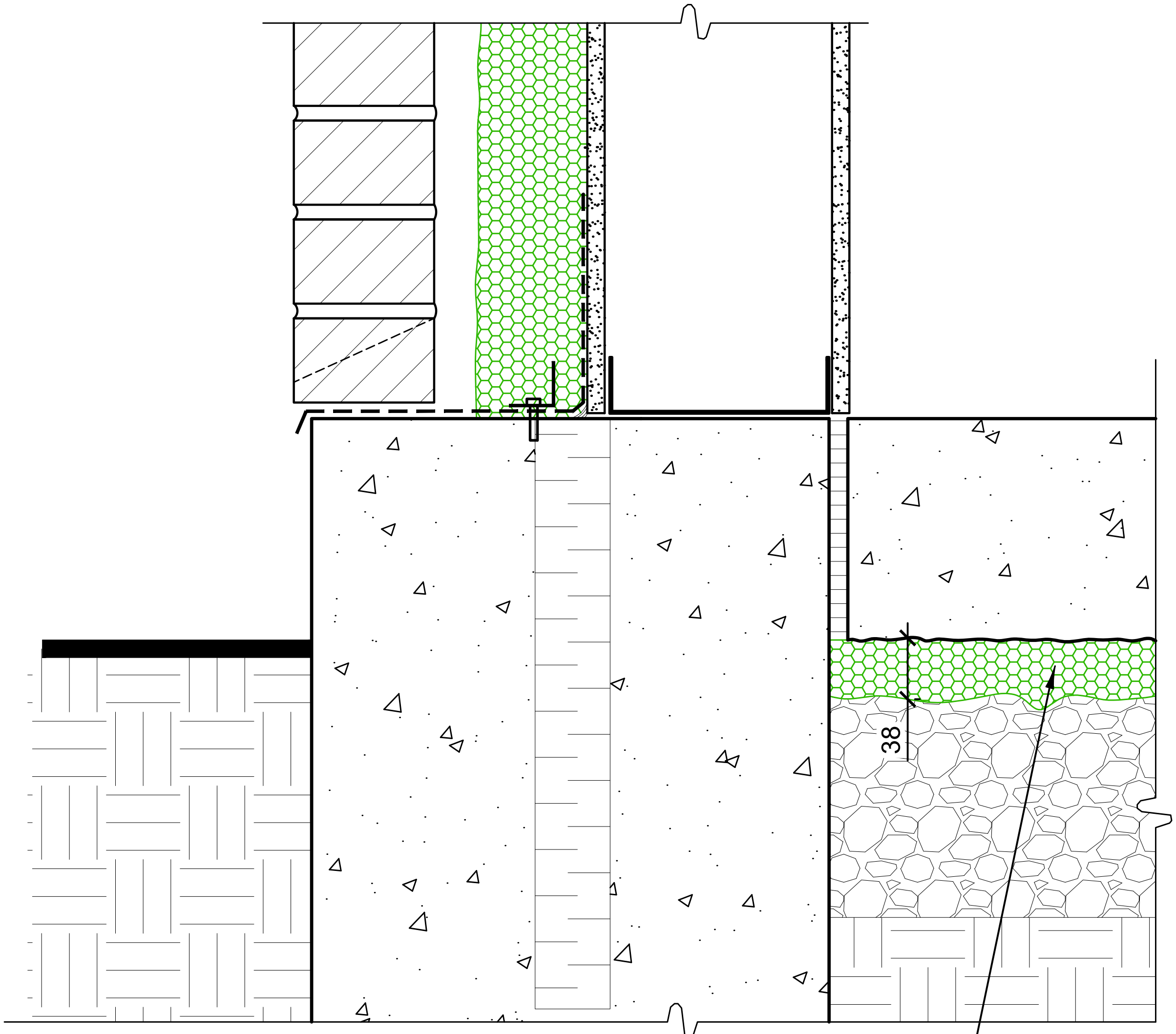
BASEMENT RETROFIT
RADON SOLUTION

HEATLOK SOYA HFO



TYPICAL DETAIL - 38mm UNDER SLAB
COMMERCIAL APPLICATION

Date: 29-04-2020

Scale: 1:5

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RADON SOLUTION

HEATLOK SOYA HFO

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BUILDING SOLUTIONS

HEATLOK® SOYA HFO™

TECHNICAL DATA SHEET

Heatlok Soya HFO / Polarfoam Soya HFO are two component, low GWP, closed cell, spray applied, rigid polyurethane foam systems. This foam product has been tested by an independent recognized laboratory and is the first product that surpasses the requirements outlined in **the most recent and stringent standard CAN/ULC S705.1-15** "Standard for thermal insulation – Spray applied rigid polyurethane foam, medium density – Material Specification". Heatlok Soya HFO/ Polarfoam Soya HFO material complies with the requirements of the National Building Code of Canada and is listed by the National Research Council Canada under CCMC Listing 14078-L, since 2017 as an insulation product. This product is commonly used as a thermal insulation product, air barrier, vapour barrier for interior, exterior applications above and below grade. Heatlok Soya HFO / Polarfoam Soya HFO uses recycled plastic materials, rapidly renewable soy oils, and 4th generation blowing agent with zero ozone depleting potential and < 1 global warming potential. This product meets all the requirements of the Paris, Kyoto and Montreal protocols. Heatlok Soya HFO/ Polarfoam Soya HFO is applied exclusively by CALIBER QAP licensed installers and contractors in accordance with the standard CAN/ULC S705.2.

PHYSICAL PROPERTIES - CCMC 14078-L - CAN/ULC S705.1-15			
ASTM D 1622-14	Apparent Core Density	2.21 lb/ft³	35.49 kg/m³
CAN/ULC S770-09	Long Term Thermal Resistance LTTR 100 mm 75 mm 50 mm	 R-24 R-17 R-11	 4.14 RSI 3.00 RSI 1.94 RSI
ASTM D 1621-16	Compressive Strength (@ 10% deflection)	27.85 lb./in²	192 kPa
ASTM D 1623-09	Tensile Strength	36.55 lb./in²	252 kPa
ASTM D 6226-15	Open Cell Content	5 %	
ASTM D 2842-12	Water Absorption by volume	1.36 %	
ASTM E 96-A-16	Water Vapour Permeance (50 mm thick, top skin removed)	0.89 perm	51 ng/Pa.s.m²
ASTM E 2178-13	Air Permeance @ 75 Pa (30.7 mm thick, top skin removed)	0.0021 L/(s•m ²)	
CAN/ULC S102-18	Flame Spread Index Corner wall test CAN/ULC S127 (included in CAN/ULC S102) Required and Declared Value (building code)	240	
ASTM D 2126-15	Dimensional Stability (28 days) (% volume change, sample without any substrate) @ -20°C @ +80°C @ +70°C & 97±3%R.H.	 -0.1 -0.3 +8.5	
CAN/ULC S774-09 (R2014)	Time of Occupancy (VOC)	1 day	
ASTM C 1338-14	Fungi Resistance	No Fungal Growth	

PHYSICAL PROPERTIES – Additional Testing			
CAN/ULC S770-03	Long Term Thermal Resistance LTTR 100 mm 75 mm 50 mm	 R-25 R-19 R-12	 4.24 RSI 3.26 RSI 2.03 RSI
UL Greenguard	Interior Air Quality	Certified Gold	
CAN/ULC S101	UL LISTED design wall FW FO7. EW24, 150mm (NBC 2010-15 art: 3.2.3.8)	Pass	
CAN/ULC S101	UL LISTED design wall FWFO7. EW25, 204mm (NBC 2010 -15 art: 3.2.3.8)	Pass	
K124/02/95* (ISO/TS 11665-13)	Radon gas resistance coefficient (for 50mm) Radon gas diffusion coefficient	17410.10^{6} s/m $1,3.10^{-10}$ m²/s	

*829 times better than a 0.15mm polyethylene sheet at a thickness of 50mm.

RECYCLED & RENEWABLE CONTENT	
Recycled Content	18 %
Renewable Materials Content	4 %

REACTIVITY PROFILE			
Cream Time	Gel Time	Tack Free Time	End of Rise
0 – 1 second	3 seconds	5 – 6 seconds	5 – 6 seconds

LIQUID COMPONENT PROPERTIES *		
PROPERTY	**ISOCYANATE**	**RESIN**
Colour	Brown	Heatlok Soya HFO: Blue Polarfoam Soya HFO: Orange
Viscosity @ 25°C	150 – 350 cps	200 – 300 cps
Specific Gravity	1.20 – 1.24	1.19 – 1.21
Shelf Life*	6 months	6 months
Mixing Ratio (volume)	100	100
Vapour Pressure @ 25°C	10^{-7} psi	8 – 9 psi
Components system storage temperature recommendation	15 @ 25°C (59 @ 77°F)	15 @ 25°C (59 @ 77°F)

*See SDS for more information.

RECOMMENDED PROCESSING PROCEDURES		
Mixing Ratio A/B (volume)	1/1	
Mixing Dynamic Pressure (minimum)	5516 kPa	800 psi
Moisture Content of Substrate	< 19%	< 19%
Maximum Thickness Per Pass	50 mm	2”
Maximum Thickness of Successive Passes	100 mm	4”
Minimum cooling time period before applying over 100 mm (4”) thick application	30 min	
Maximum Thickness in 24 h	200 mm	8”
PRODUCT VERSION	**VERSION APPLICATION TEMPERATURES (AIR, SUBSTRATE, & CURING)**	**LIQUID TEMPERATURE AT THE GUN**
Summer Version	30 @ 5°C (41 @ 86°F)	35 @ 46°C (95 @ 115°F)
Winter Version	5 @ -10°C (41 @ 14°F)	38 @ 49°C (100 @ 120°F)

General Information: It is recommended that the foam be covered with an approved thermal barrier in accordance with the applicable building code when used in buildings and covered by a UV coating when used outside. This product should not be used when the continuous service temperature of the substrate is outside the range of -60°C to 80°C (-76°F to 180°F). Do not apply excessive thickness in one application it may cause spontaneous combustion of the foam hours after the application. Respect the recommended procedures. Heatlok Soya HFO is green in color. Polarfoam Soya HFO is orange in color.

Disclaimer: The information herein is to assist customers in determining whether our products are suitable for their applications. We request that customers inspect and test our products before use and satisfy themselves as to contents and suitability. Nothing herein shall constitute a warranty, expressed or implied, including any warranty of merchantability or fitness, nor is protection from any law or patent inferred. All patent rights are reserved. The foam product is combustible and must be protected in accordance with applicable codes. Protect from direct flame and spark contact, around hot work for example. The exclusive remedy for all proven claims is replacement of our materials.

CCMC EVALUATION 14078-L

LISTED

GREENGUARD GOLD

ZeroODS

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FACULTY OF CIVIL ENGINEERING – TEST LABORATORY
Accredited by ČIA, accreditation No. 1048
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L 1048

COMPARISON OF RADON BARRIER PROPERTIES OF HEATLOK SOYA HFO FOAM INSULATION WITH PE MEMBRANE

Radon diffusion coefficient *D* is a material constant that shows the ability of radon to diffuse in the material. The radon diffusion coefficient alone cannot demonstrate the real barrier properties of a particular waterproofing product.

The ability of a material to form an efficient barrier against radon diffusion is expressed by the **radon resistance R_{Rn}** that is defined according to the following equation.

$$R_{Rn} = \frac{\sinh d/l}{\lambda . l} \qquad [\mathrm{s/m}]$$

where d is the thickness of the material [m], λ is the radon decay constant [$2{,}1.10^{-6}$ s^{-1}] and l is the radon diffusion length in the material [m]. Radon resistance must be always stated together with the thickness of the material. Greater value of the radon resistance means better barrier properties.

Comparison of tested materials

Sample	***d* [mm]**	***D* [m²/s]**	**R_{Rn} [s/m]**	**R_H/R_{PE} [-]**
PE (CAN-CGSB-51.34-M)	0,15	$7{,}2.10^{-12}$	21.10^6	-
Heatlok Soya HFO	15	$1{,}3.10^{-10}$	199.10^6	9,5
	20		382.10^6	18,2
	25		725.10^6	34,5
	30		$1\,370.10^6$	65,2
	50		$17\,410.10^6$	829,0

Legend: R_H – radon resistance of Heatlok Soya HFO foam insulation, R_{PE} – radon resistance of PE

As can be seen from the Table, the barrier properties of Heatlok Soya HFO foam insulation of specified thicknesses are at least 9,5 times better than those of PE membrane of the thickness of 0,15 mm.

Praha, 18.9.2018

Martin Jiránek

VYSOKÉ UČENÍ TECHNICKÉ V PRAZE
Akreditovaná zkušební laboratoř FSv č. 1048
OL 124

Case Study

Basement Flooding

Date:
May 29, 2017

Location:
Montreal, Quebec, Canada

Construction Type:
Residential

Exterior plaster, 8” of concrete, 2.5” of Airmetic Soya, 2”x4” wood studs spaced 1” from the foundation wall, air space, 0.5” gypsum.

Product:
Airmetic Soya
Closed Cell Spray Foam Insulation

Situation

On May 22, 2017, following the river flooding in the spring, Demilec visited a flooded basement with 4’ of contaminated water (photo 1). The basement was insulated entirely with Airmetic Soya closed-cell spray foam. The purpose of this visit was to check the condition of the foam insulation after 5 days of immersion. The contaminated water was mixed with sewage and oil spillage.

Solution

Prior to the visit, the surface of all the walls had been washed and the basement had been cleaned with a pressure washer. Dehumidifiers and industrial fans had been in operation for 5 days (photo 2). In order to verify the effects of the flooding on the spray foam insulation, samples were taken on site for laboratory testing. Readings of the moisture content in the wood were made in several places (photo 3).

Even after being submerged for several days, the spray foam insulation was dry and showed no signs of deterioration. Water absorption and mold growth were not an issue. The uncovered wood dried with the help of dehumidifiers and fans. However, the portion of the wood studs embedded in the polyurethane were still moist.

Conclusion

The existing spray foam insulation may remain in place, but the drying of the wood must be facilitated with industrial equipment. It is important to thoroughly clean the joints between the wood structure and the floor to allow the wood to dry out as quickly as possible. The wood must reach a moisture content of less than 19% in order to allow the installation of finishing panels, as required by the building code (Article 9.3.2.5.).

For more information, contact the Demilec Building Science Department at 817-640-4900. www.Demilec.com

REPORT ON THE SUITABILITY OF DEMILEC HEATLOK™ SOYA AS A SOIL GAS BARRIER FOR RADON

HEATLOK SOYA
SPRAY POLYURETHANE FOAM

Prepared for:

Demilec Heatlok Soya

870 Cure Boivin
Boisbriand, Quebec
J7G 2A7

Project: 2-012016
February 8th, 2017

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Professional Engineers Ontario

APGO

REPORT ON THE SUITABILITY OF DEMILEC HEATLOK™ SOYA AS A SOIL GAS BARRIER FOR RADON

1.0 BACKGROUND

Current national and provincial building codes of Canada contain provisions to control the ingress of ground sourced radon (*soil gas*) into buildings to protect building occupants from an increased risk of radon induced lung cancer. “Radon overexposure is the leading cause of lung cancer in non-smokers and it’s estimated that in Canada there are more than 3300 lung cancer deaths related to radon each year.” (Canadian Cancer Society, 2016). Contrary to previous conventional thinking, the distribution of radon prone soils is not isolated to a few geographic areas, and virtually all indoor building environments will contain radon to some degree. In March 2012, Health Canada completed a cross-county survey of radon concentrations in nearly 14,000 homes. “The results from this two-year study concluded that 6.9% of Canadians are living in homes with radon levels above the current radon “actionable level” of 200 Becquerels per cubic metre of air (Bq/m^3)” (Canadian Nuclear Safety Commission, 2012). The only way to determine the radon levels are in a building is to test it after construction under normal occupied conditions. There is currently no reliable or affordable method to determine if a building will or won’t have high radon levels prior to its construction; justifying the code requirements to control the ingress of radon for all buildings.

Soil gas ingress is managed in new construction and renovations by: i) applying soil gas barriers to ground contact floors, foundation walls and roofs, ii) providing a gas collection layer (e.g. clear stone or gas mat) under all ground contact floors, iii) installing a piping system for the extraction of soil gas from under the floors, iv) sealing seams, cracks, penetrations and all openings in ground contact floors, walls and roofs; and iv) testing the radon levels in the building after construction. In the event that the indoor radon concentrations exceed the Health Canada action level the piping system can be connected to an extraction fan to control radon entry and exhaust the accumulated radon safely outdoors.

Some building codes do not currently mandate indoor radon testing after construction. “There is an entrenched belief that simply extending the continuity of the air barrier through the building foundation, as prescribed by the national and some provincial building codes, is sufficient by itself to control indoor radon levels. These views are contrary to the findings of Health Canada and extensive evidence and experience from relevant agencies in the United States and Europe.” (Decker et. al., 2014). Obtaining a perfect air barrier/soil gas barrier is virtually imposibe using conventional construction methods (e.g. sheeting and taping). Spray-applied soil gas barriers (i.e. Demilec Heatlok™ Soya) dramatically increase the efficacy of soil gas control systems due to the high level of air tightness provided. In addition, at 12 millimeter (mm) thickness, Demilec Heatlok™ Soya provides four (4) times more resistance to radon diffusion than 6-mil polyethylene sheeting and where applied, eliminates the requirement for manual caulking of seams, cracks, penetrations and saw cuts in ground contact walls, floors and roofs.

Ground sourced radon enters buildings through leakage and diffusion mechanisms. Soil gas leakage occurs through all openings, cracks, seams and penetrations in ground contact walls, floors and roofs and is driven primarily by stack-effect induced pressure differentials across the building envelope. Mechanical ventilation systems and occupant activity also affect pressure differentials across the building envelope and therefore affect the rate of radon ingress. The pressure differentials required to draw radon into a building are as low as 0.025 Pascal (Pa) or 0.0001 inches of water column (w.c.) which are much lower than the typical pressure differentials imposed on a building. "It has been known for some time that convective flow (leakage) is the main driving force behind elevated radon levels in homes and buildings due to the reduction of pressure relative to the surrounding soil. Diffusion is usually considered the second major driving force and can sometimes result in high indoor radon concentrations. Therefore, barriers that can retard both mechanisms will increase the resistance of the building against radon penetration" (W. Z. Daoud, 1999)

National and some provincial building codes of Canada prescribe the use of polyethylene sheeting soil gas barrier under the slab. "While vapour permeance characteristics of these membranes are well known and specified in Canadian standards, their radon diffusion coefficients are not" (Chen, 2009). This report compares the radon diffusion coefficients of Demilec Heatlok™ Soya with polyethylene sheeting and other commonly used soil gas barriers to demonstrate its suitability as a radon barrier.

2.0 BUILDING CODE REQUIREMENTS

The National Building Code of Canada, as well as provincial building codes of British Columbia, Ontario and Quebec, stipulate radon control in Part 9 (residential construction). In general, these codes describe the use of bituminous dampproofing on foundation exteriors and the use of 0.15 millimeter (mm) polyethylene sheeting under floor slabs as radon gas barriers. The selection criteria for these materials may be related to their known performance as air or vapour barriers. Polyethylene sheeting is often used in building assemblies as an air barrier and or a vapour barrier. Canadian building code requires vapour barrier materials have a permeance of not greater than 60 ng/(Pa·s·m^2) defined by the ASTM E 96/E 96M "Water Vapour Transmission of Materials" using desiccant (dry cup) method; and air barrier materials have an air leakage characteristic less than 0.1 L/(s·m^2) at 75 Pa, or in the case of Ontario not greater than 0.02 L/(s·m^2) at 75 Pa and conform to the CAN/ULC-S741, "Air Barrier Materials – Specification". Polyethylene film at a thickness of 0.15 mm has a dry cup permeance of 3 ng/(Pa·s·m^2) (NRC-CNRC, 1995) and has no measureable air leakage (CMHC SCHL, 1999) making it a sutiable material for such application.

No performance criterion for the maximum permissible rate of radon diffusion through a radon barrier has been established in Canadian building code. This is likely due to a focus on controlling the primary mechanism of radon entry (soil gas leakage) instead of diffusion. "Often used as a vapour barrier polyethelyene is inexpensive to buy. However, it fails or barely meets most air barrier requirements other than air impermeability. It is difficult and relatively expensive to achieve continuity, especially since it is pierced by services and enclosure penetrations" as well as foot traffic during construction (Straube, 2007). Angular gravel can cause significant damage to polyethylene sheeting and rigid board insulation barriers.

Establishing an acceptable radon leakage performance criterion for radon barriers is as straightforward as selecting a building material with low air leakage rates; establishing an acceptable radon permeance rate is more difficult. "The effectiveness of a membrane for reducing the movement of radon into a building is dependent upon the material composition, material thickness, and sealing of the membrane seals" (Kitto, 2016); "of course none of the materials can stop radon flow if they are not properly (i.e. in a gas-tight way) installed" (Walczak, 2015).

3.0 RADON DIFFUSION COEFFICIENTS OF BARRIER MATERIALS

Radon diffusion coefficients are expressed as the amount of radon penetrating a one (1) meter thick material over an area of one (1) square meter per unit time during a radon concentration gradient of 1 or more Bq/m^3 and pressure gradient of zero.

It is not prudent to assume that if a material can adequately resist water vapour diffusion that it can adequately resist radon diffusion as the radon atom is approximately twice the size of a water molecule. Although governed by Ficks Law, radon diffusion is more dynamic than water diffusion as the nuclear decay of radon gas (3.8 day half-life) changes the element over time. Radon diffusion is determined by measuring the flux of a material placed between two chambers with one chamber containing a radon source typically 40 to 50 thousand Becquerels per cubic metre of air (MBq/m^3). The radon diffuses through the sample and radon concentrations on in both chambers (both sides of the material) are measured continuously. When a steady state radon concentration profile exists within the material, the upper chamber is flushed and the increase in radon concentration in the upper chamber is measured. "The radon diffusion coefficient of a material is then determined based on the time-dependent curve of the radon concentration increase in the upper chamber by solving the one-dimensional diffusion equation:" (Chen, 2009)

$$\frac{\partial}{\partial x}\left(D\frac{\partial C}{\partial x}\right) - \lambda \mathrm{x} C = \frac{\partial C}{\partial t}$$

where D is the radon diffusion coefficient ($m^2\ s^{-1}$), λ the radon decay constant ($2.1\text{x}10^{-6}$ s^{-1}), C the radon concentration within the material (Bq m^{-3}) and t the time (s).

Radon diffusion coefficients of common vapour barrier membranes used in the Canadian building construction industry were determined in a study conducted by Chen et. al (Chen, 2009). A total of six (6) polyethylene sheet materials of 0.15 mm thickness were tested at the Faculty of Civil Engineering, Czech Technical University in accordance with the K124/02/95 method accredited by the Czech Accreditation Institute. This study reported radon diffusion coefficients from 9.4×10^{-12} to 2.1×10^{-11} m^2/s with an average of 1.4×10^{-11} m^2/s which is consistent with the average radon diffusion coefficients of 0.15 mm polyethylene of 1.6×10^{-11} m^2/s reported in a study by W.Z. Daoud and K. J. Renken. (W. Z. Daoud, 1999). "Measurements conducted on over 120 radon-proof materials varied widely from 10^{-15} to 10^{-8} m^2/s. The diffusion coefficients for most radon-proof materials ranged from 10^{-12} m^2/s to 10^{-10} m^2/s. Vapour barrier materials used in Canadian building construction showed radon diffusion coefficients in the range of 5×10^{-12} to 2×10^{-11} m^2/s, which are comparable with the most commonly used European radon-proof materials." (Chen, 2009). Based on the results Chen et. al. concluded that "all of the tested membranes (0.15 mm polyethylene) can serve as a barrier against soil gas radon" (Chen, 2009).

The ideal radon gas barrier would have: excellent resistant to air/soil gas leakage, excellent adhesion to building elements to maintain seals, durability during the process construction and the life of the building, continuity, low radon permeance (diffusion coefficient) and be immune to the installation deficiencies (e.g. inadequate or improper taping and sealing).

4.0 SUITABILITY OF DEMILEC HEATLOK™ SOYA AS A SOIL GAS BARRIER FOR RADON

Demilec Heatlok™ Soya is a closed-cell (<10% open cells) foam insulation with a density of 33.6 to 36.8 kilograms per cubic meter (kg/m^3), 2.1 to 2.3 pounds per cubic foot (lb/ft^3). It has a water vapour permeance of 37 $ng/(Pa \cdot s \cdot m^2)$ at 50mm thickness and an air leakage rate of 0.00004 $L/(s \cdot m^2)$ at 75 Pa at 25 to 30 mm thickness. These properties conform to the National Building Code of Canada, as well as the provincial building codes of British Columbia, Ontario and Quebec making Demilec Heatlok™ Soya an air barrier at 25 mm and vapour barrier at 32 mm.

To determine radon barrier suitability, Demilec Heatlok™ Soya was laboratory tested at the Faculty of Civil Engineering, Czech Technical University in accordance with the K124/02/95 method accredited by the Czech Accreditation Institute to determine its radon diffusion coefficient. Demilec Heatlok™ Soya was reported to have a radon diffusion coefficient of 1.4×10^{-10} m^2/s which falls within the radon diffusion coefficients for most radon-proof materials (10^{-12} m^2/s to 10^{-10} m^2/s) identified by Chen et. al.

“It is well known that the lower the radon diffusion coefficient, the better are the barrier properties against radon penetration through the membrane” (Chen, 2009). As with all diffusion rates the material thickness must always be taken into consideration when determining the permeability of the subject matter (i.e. radon) through the material. As material (i.e. barrier) thickness increases, radon diffusion decreases resulting in a more effective resistance to radon transport by diffusion. The radon resistance of a material is defined by the equation:

$$R_{Rn} = \frac{d}{D}$$

where D is the radon diffusion coefficient ($m^2\ s^{-1}$), d is the thickness of the material (m).

The range of radon diffusion coefficients for 0.15mm polyethylene reported by Chen et. al. at $9.4x10^{-12}$ to $2.1x10^{-11}$ m^2/s provide radon resistance between $7.5x10^6$ and $16.3x10^6$ (s/m) respectively. At typical application thicknesses (38 mm [1.5 inches] for unheated slabs and 50 mm [2 inches] for heated slabs) Demilec Heatlok™ Soya provides a radon resistance of $272x10^6$ to $357x10^6$ (s/m) respectively which is approximately 17 to 47 times more resistant to radon diffusion than 0.15 mm polyethelyene.

Based on the above Demilec Heatlok™ Soya outperforms 0.15 mm polyethelyene as a diffusive radon barrier. An additional advantage is that “the application of 50 mm (2 inches) closed-cell spray foam over granular as under-slab insulation will attain a continuous air barrier. The spray foam is very likely to survive the pouring of the concrete intact (unlike 0.15mm polyethylene) and will outperform manual sealing measures increasing the efficacy of the gas barrier.” (Decker et. al., 2014) The same would hold true for the application of Demilec Heatlok™ Soya as a radon barrier over ground contact walls and roofs.

5.0 CONCLUSIONS

Careful review of the above information demonstrates Demilec Heatlok™ Soya alone is an adequate radon barrier at far less than typical application thicknesses of 38 to 50 mm and can outperform conventional 0.15 mm polyethylene installations by controlling radon diffusion and leakage transport mechanisms. Applying additional radon barrier materials with Demilec Heatlok™ Soya would be unnecessary.

Considering the majority of soil gas intrusion is through air leakage (i.e. through joints, cracks, and penetrations) it is essential to ensure good sealing of joints, cracks, and penetrations and good continuity of the soil gas barrier. Through its ability to expand into crevasses and adhere to building elements, properly applied Demilec Heatlok™ Soya will provide a continuous soil gas barrier, both under-slab and on foundation walls and roofs. Properly applied Demilec Heatlok™ Soya can reduce construction deficiencies inherent to taped or caulked radon barrier system assemblies.

Considerable cost savings may also be realized by using Demilec Heatlok™ Soya as "the cost of sealing (radon) entry routes is highly variable. It can range from a few hundred dollars to $2,000 or more. Although the material cost (caulking and polyethylene used in conventional construction) is relatively low, it is very labour-intensive to do a comprehensive job. As the (building) ages and settles, the seals can deteriorate, and new cracks or entry routes can appear. As a result, there will be an ongoing cost to maintain the seals or an increase in indoor radon levels" (Health Canada, 2013). Kitto and Perazzo "emphasized the importance of selecting a high-performance radon barrier, and sealing of the seams and holes that may occur during placement of the barrier at a building site." (Kitto, 2016). Using Demilec Heatlok™ Soya as a radon barrier can deliver excellent control over radon ingress, provide a high degree of certainty of project success, alleviate labour costs, and decrease future liabilities.

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6.0 LIMITATIONS

The research, information and conclusions detailed in this report were carried out by trained professional and technical staff in accordance with generally accepted engineering, environmental, industrial hygiene and building science practice. Recommendations made in this report have been made in the context of existing industry accepted guidelines, which were in place at the date of this report and as they relate to the use of Demilec Heatlok™ Soya as a radon barrier only. It is the responsibility of the designer, engineer, architect, builder, contractor, owner etc. to ensure the use of Demilec Heatlok™ Soya is in compliance with all current and applicable acts, regulations, codes, standards, guidelines, by-laws and industry best practice governing the work.

In preparing this report, Safetech Environmental Limited (SEL) relied on information supplied by others. Except as expressly set-out in this report, SEL has not made any independent verification of such information.

Conclusions are based on the information, documents, and specifications made available at the time of this assignment. If any information becomes available that differs from the findings in this report, we request that we be notified immediately to reassess the conclusions provided herein. SEL makes no warranty in regards to the longevity of the spray-on material in keeping it's specified properties over time.

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