IAEA
International Atomic Energy Agency

Virtual Expert Mission to Portugal on Radon Action Plan

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6 – 9 October 2020

Virtual event

6. Radon prevention

Training of building professionals (I)

Recommendations from RADPAR report "Radon and Remediation : The RADPAR recommendations":

- Training of an adequate number of remediators
- Properly trained remediators should be available at local level
- Radon topics should be included in training/curricula of all building professionals (architects, builders, building inspectors, etc.)
- Courses should be designed for: architects, designers, building engineers, contractors, professionals from construction companies and building industry, personnel from building inspection authorities, planning offices, etc
- Content, duration and frequency should depend on the level of knowledge of the audience.
- Could end with exam or/and certification, could be requested to repeat at certain periodicity.

Training of building professionals (II)

Possible content of training courses *(based on RADPAR recommendations - http://web.jrc.ec.europa.eu/radpar/documents.cfm)*

- General information about radon (geology, mapping…)
- Health effects
- Legislation related to the radon issue
- Basics of radon measurements
- Radon in buildings (sources, entry routes…)
- Information about construction habits
    - Building types and foundation types
    - Building materials
    - Air-tightness of building shell
    - Building ventilation and indoor air quality
    - Heating systems

Training of building professionals (III)

- Principles of preventive and corrective measures
- Preventive measures
    - Input information (radon risk of foundation soils)
    - Conception of prevention
    - Examples of integration into the design
    - Products and systems
- Corrective actions
    - Diagnostic measurements
    - Building survey
    - Adaptation and integration of corrective actions
    - Examples of corrective actions
    - Products and systems
- Theoretical and practical exercises (visits, case studies)
- Examination

Radon Prevention

- Can be incorporated into construction
- Use (switch on) if needed
- Can improve other aspects of indoor air quality
- Implemented by means of national building codes
- Measurements of Rn in soil gas and soil permeability for building site could provide information about the need of preventive measures
- Remember that energy efficient homes affect concentration of radon and building codes must take this into consideration.

Radon Prevention methods

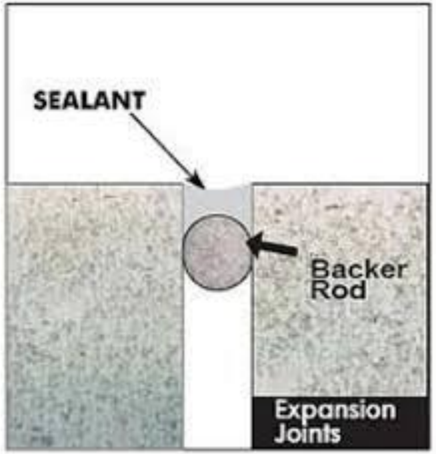
Radon impermeable membrane (anti-radon membrane)

Sealing of construction elements

Active or passive depressurisation (or sub-floor void ventilation)

Sealing

- Pipes and other utility penetrations through the slab
- All cracks, joints, and openings in the concrete slab
- Openings greater than 13 mm in width need to be pre-filled with backer rod or comparable material.
- Sealing material to be compatible with the surfaces to which it is applied
- **Sealing needs to be inspected** upon completion to ensure the airtightness to ensure that any further radon mitigations steps to be taken will be successful.

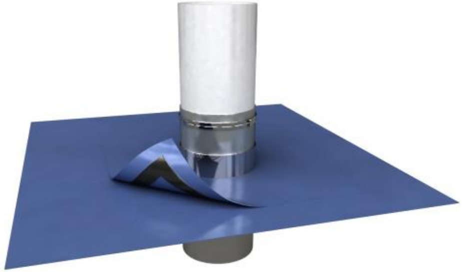


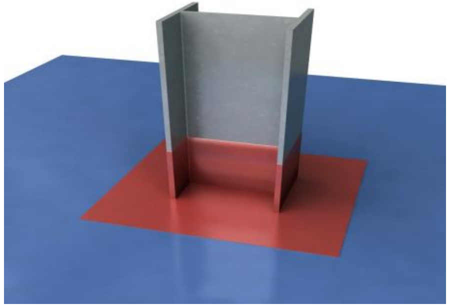
https://www.bestmaterials.com/Backer_Rod.aspx

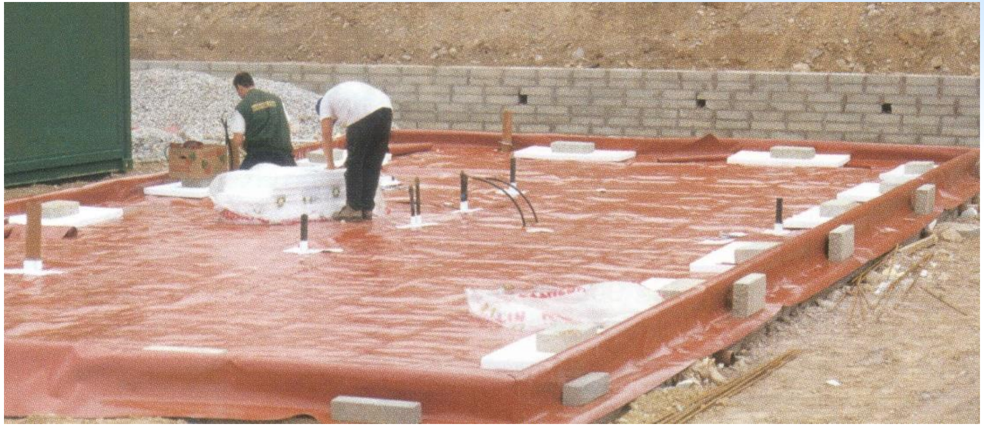
Membranes

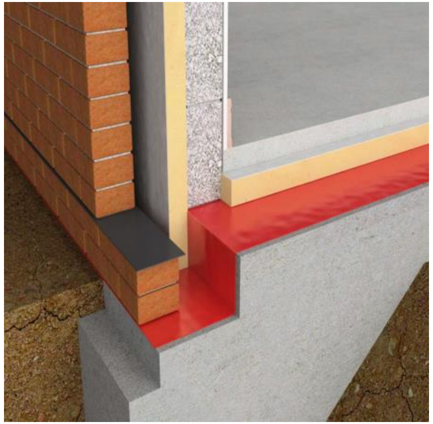
- There are many different types and thicknesses of membrane
- Installed beneath poured concrete slabs for two reasons:
  - the membrane holds the concrete in place while it cures so the concrete does not fill the permeable gravel layer,
  - the membrane can assist in bridging any future cracks that occur in the concrete after all the pertinent sealing has been done.
- Membranes used for sealing crawl spaces need to be durable and sealed airtight to stop any soil gas entry into the structure.
- Membrane pieces need to be overlapped by 300 mm and sealed to one another in a permanent airtight manner.
- Crawl space membranes also need to be sealed in a permanent airtight manner to the building foundation walls, interior foundation supports, utility penetrations and any other penetrations through the membrane.
- The sealing needs **to be inspected** upon completion to ensure high level of airtightness to ensure that any further radon reduction steps are successful.

Radon membrane installation







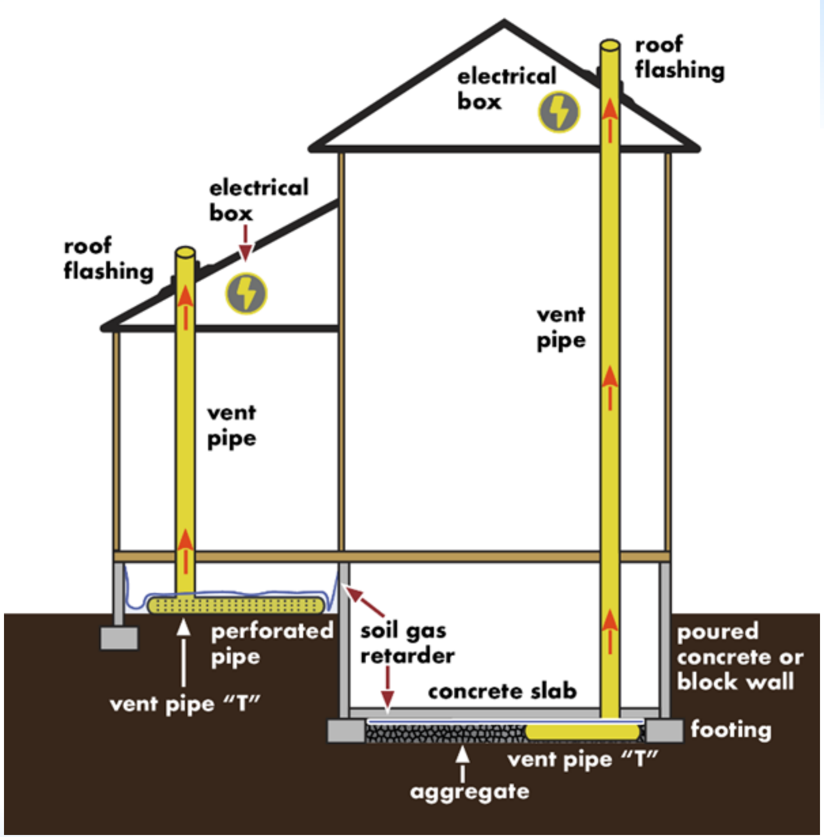


- Radon membrane extending to the outside leaf.
- All pipe penetrations sealed.

Information and images provided by Emond Smith, Ireland

Active and passive depressurization - components

- Passive depressurization could be preferred, but not always enough
- The basic components needed for depressurization:
  - Electric power outlets and sockets,
  - Permeable layers,
  - **Fan,**
  - Vent pipes,
  - Roof vent, vent hood and pipe connections,
  - Sealing and membranes,
  - Operation monitoring.



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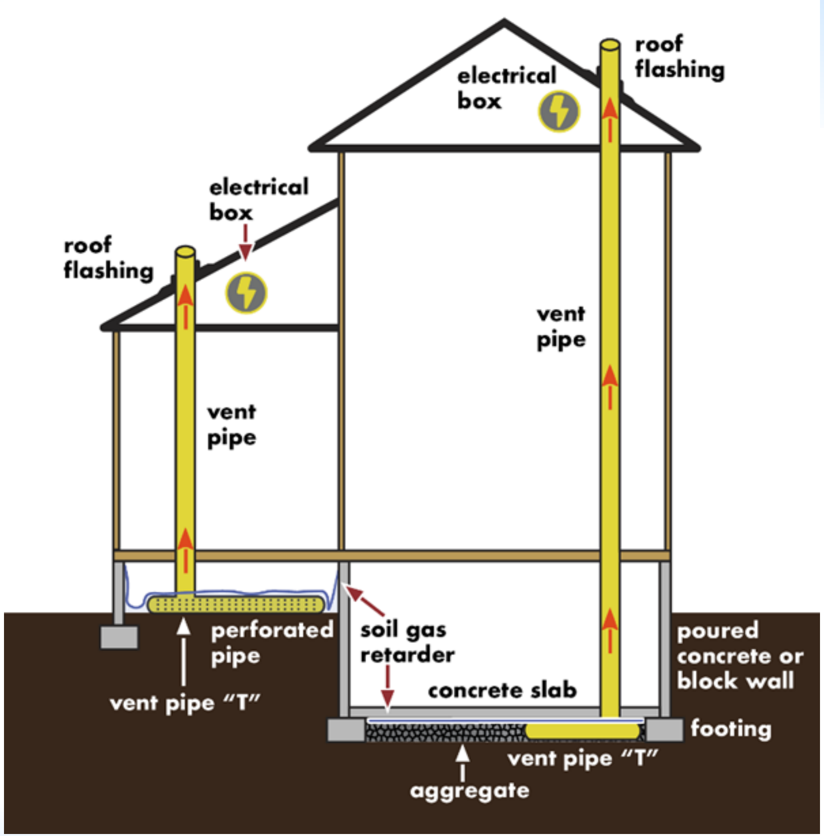

Active and passive depressurization - components

- Additional **electrical socket** might need to be installed near the vent pipe where a future fan may be placed.
- **Permeable layer** of aggregate is needed:
  - minimum 100 mm thickness
  - to be spread under all areas within the building's foundation walls
  - might consist of material that will pass through a 50 mm sieve and be retained by a 6 mm sieve (river pebble, crushed rock or recycled fill materials work equally well if permeable)
  - Alternative method - uniform layer of sand, native or fill, with a minimum thickness of 100 mm, overlain by a layer or strips of geotextile drainage matting designed to allow the lateral flow of soil gases may also be used.
- **Radon fan** must be
- rated for continuous operation needs
- installed inside the vertical vent pipe
- preferred placement - outside the building
- smallest energy consumption but capable of producing the desired pressure field extension and airflow
- example of a radon fan used in single family home system activation is one that provides a minimum of 85 m3/h at 125 Pa

OBS!

- not be installed inside the building, basement, or crawl space
- not to be located where it may create positive pressure in any portion of the vent pipe located inside the building.

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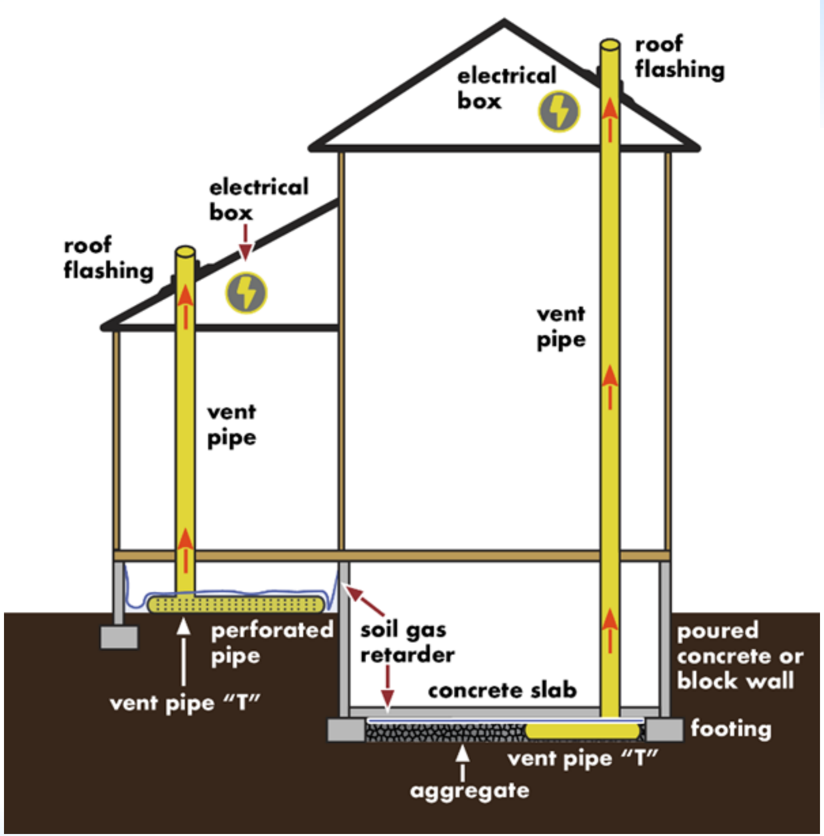

Active and passive depressurization – components

Vent pipe(s)

- runs vertically through the building and the roof, directing the soil gases to the outdoors
- minimum 75 mm to 100 mm diameter
- connected to the “T” in the gas permeable layer.
- if the building has a sump pit or drain-tile system, the vent pipe can be inserted directly into the sump pit or connected to the drain-tile.
- fully sealed at all joints to ensure that the pipe work is airtight
- extends up from the radon collection point to exhaust point terminating
- minimum of 300 mm above the roof
- at least 3 metres away from any window or other opening into the heated spaces of the building
- if routed through unheated spaces need to be insulated so that the air temperature in the pipe does not change significantly
- need not be insulated for temperature and condensation reasons but may need insulating for noise reduction
- if interior footings or other barriers separate the gas-permeable material into two or more areas - each area needs to be fitted with an individual radon mitigation.

Vent pipe drainage:

- provide drainage to the ground beneath the membrane.

Vent pipe accessibility:

- provide space around the vent pipe for installation of a fan in the future, if needed.
- minimum of 600 mm in diameter, centred on the axis of the vent pipe, and needs to extend a minimum distance of 900 mm vertically.

Identification:

- clearly visible
- at least one label on each storey of the building, in attics and in crawl spaces.
- label could read *Radon Gas Vent System* or similar.

Combined basement/crawl space or slab-on-grade/crawl space foundations needs to have separate radon vent pipes installed in each type of foundation. Each radon vent pipe has to terminate above the roof or has to be connected to a single vent pipe that terminatesabove the roof.

Roof flashing or hood - around the vent pipe exit on the roof to prevent water leakage

Active and passive depressurization - components

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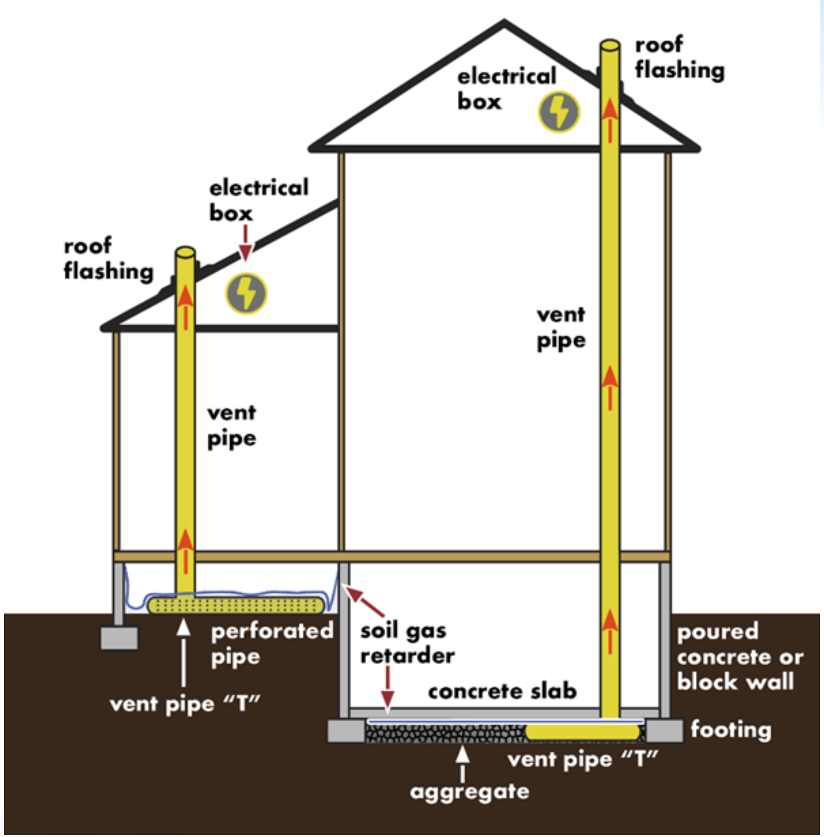

Active and passive depressurization - components

- All potential soil gas entry points into the building need to be sealed with caulk or other durable sealing material
- All possible entry points need to be cleared of loose material prior to sealing.
- The sump pit needs to be covered and sealed and inspected upon completion to ensure airtightness.
- Special attention needs to be paid to the following spots in a construction:
  - Floor openings around bathtubs, showers, water closets, pipes, wires, or other objects that penetrate the membrane and the concrete slab or other floor systems;
  - Control joints, isolation joints, construction joints, or any other joints in the concrete slab, or the joint between the con crete slab and a foundation wall;
  - Joints, cracks, or other openings around all penetrations of both exterior and interior surfaces of foundation walls.
- Hollow block masonry foundation walls need to be constructed with either:
  - A continuous course of solid masonry at or above the exterior ground surface;
  - One course of masonry grouted solid at or above the exterior ground surface;
  - A solid concrete beam at or above the finished exterior ground surface;
  - When a brick veneer or other masonry ledge is installed, the masonry course immediately below the veneer or ledge needs to be solid or filled.
- An appropriate membrane is placed over the gas permeable layer.

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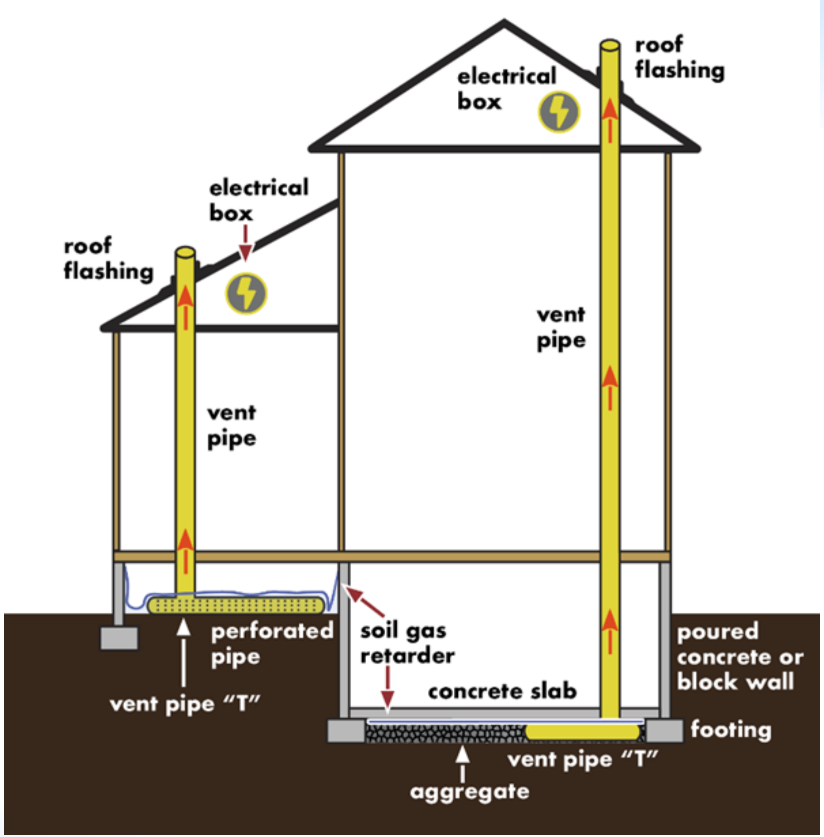


Active and passive depressurization - components

- After the building is occupied - radon measurements
- If radon levels above the national reference level - the passive system to be activated by installing a radon fan.
- An audible alarm, flashing light, a manometer, or other similar device may be installed to indicate when the fan is not operating.
- Support - system activation devices are available as well (measure radon concentration and turn on the fan).

7.Radon mitigation

Radon Remediation (I)

- Prevent Rn from entering building from soil or remove Rn from indoors
- Can be active or passive (cost vs effectiveness)
- Effectiveness vary
- Corrective measures may need to take national construction practices into account
- Optimization – reduce radon significantly, not just below the reference level
- After corrective actions – measure Rn activity, repeat periodically
- Retrofitting of buildings for energy efficiency can affect radon activity – must be reflected in building codes.

- Any radon mitigation should be done or guided by a professional

Radon mitigation (II)

To be successful, it is important that the radon mitigation professional:

- Is appropriately trained, with an understanding of how radon flows and moves into and through a building;
- Has an understanding of relevant radon measurement and diagnostic techniques;
- Has a detailed understanding of construction techniques and indoor heating and ventilation;
- Possesses a sufficient knowledge and has experience of different kinds of mitigation techniques;
- Carries out the work in a professional manner;
- Provides appropriate operating and maintenance instructions to the building occupier, owner or building manager.

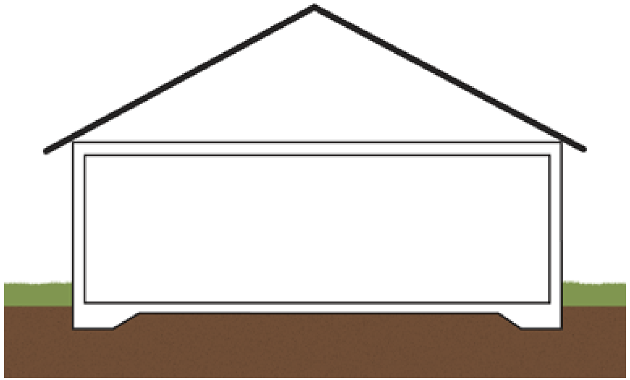
Types of foundation (I)

Four foundation types:

- slab-on-grade,
- crawl space,
- basement with footings, or
- basement with load bearing slab and wall construction.

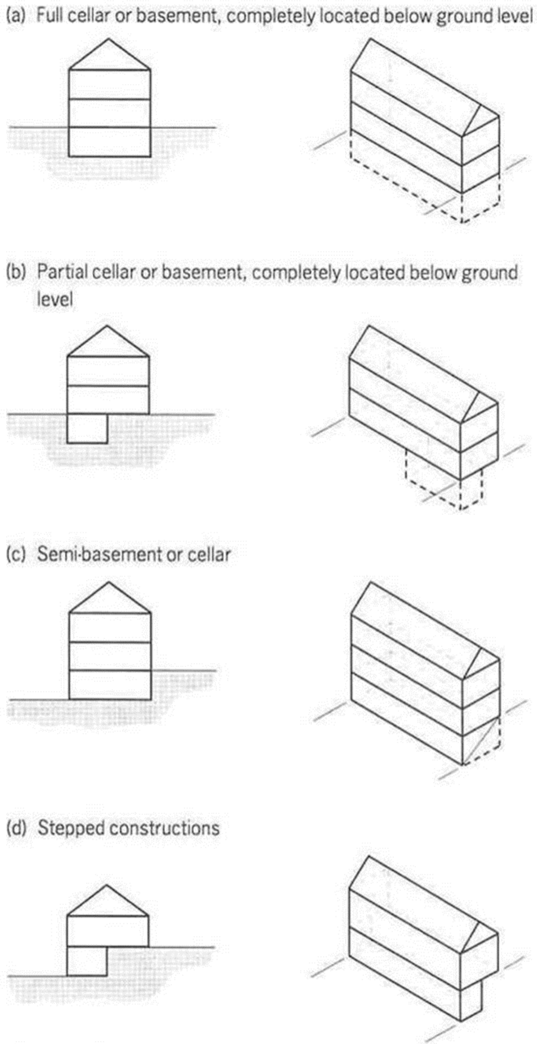
- Most buildings will use only one foundation type
- Where building extensions have been added over the years - may use several foundation types
- Important to identify each foundation type - properly address radon prevention and mitigation
- Basements include occupied spaces fully or partially below ground level.
- All buildings have some contact with the ground - potentially have a radon problem
- Radon reduction measures may fail if the floors and walls forming the foundations are overlooked or ignored

Types of foundation (II)



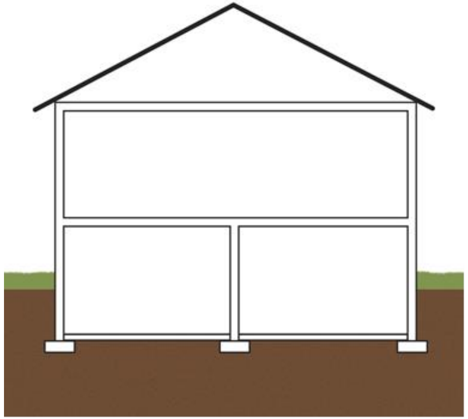
Slab on grade type of foundation

Two sub-types of slab-on-grade foundation:
- The superstructure and/or walls built-off the floor slab;
- The superstructure and/or walls built-off strip or pad foundations, with the slab poured after the foundation walls have been installed.



Different kinds of cellars and basements
(reproduced with permission of IHS Markit)

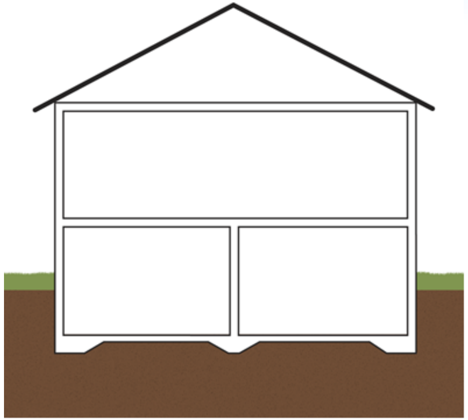
Types of foundation (III)



***Basement with footings*.**

House is built on footings with the floors poured between the basement walls.

Basement walls and floor are not created at the same time.

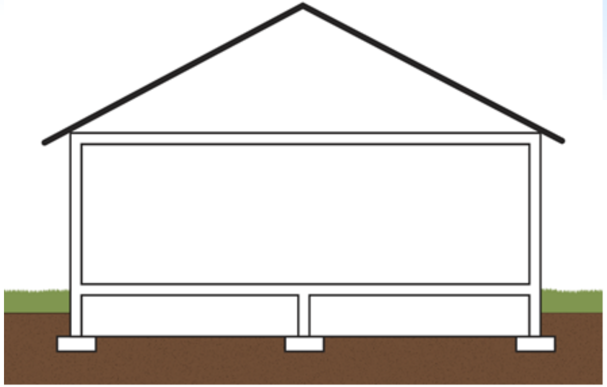


***Basement with load bearing slab*.**

House is built on a solid load bearing slab.

This allows for fewer radon entry points.

Basement walls and floors are created at the same time.



Crawl space.

Foundation with an open area beneath the lowest occupied space of the building.

Lowest living or occupied level is above the crawl space and is usually elevated 200 mm above grade.

Crawl spaces are not habitable areas

May contain utilities or mechanical ductwork that serves the rest of the building.

Crawl spaces are often uncovered earthen material that can be a source of radon.

If left untreated, can contribute to elevated radon levels in the building.

May have a poured concrete floor - needs to be provided with under floor vents to ensure ventilation under the floor to remove moisture

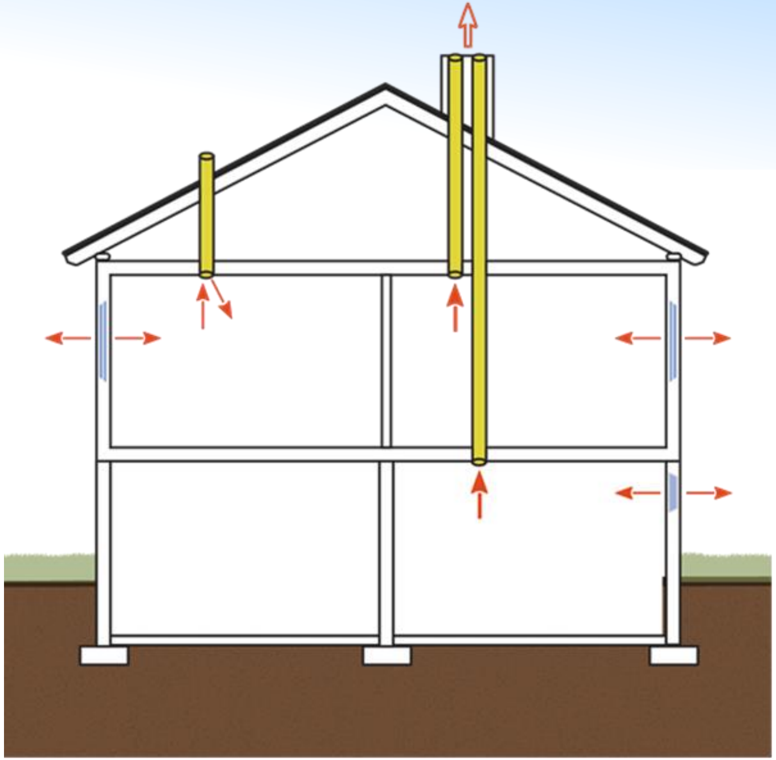
Types of ventilation (I)

Three common types of ventilation system:

- natural draught ventilation;
- mechanical exhaust air ventilation system; and
- mechanical supply and exhaust air ventilation system having different influence on indoor radon accumulation or ventilation.

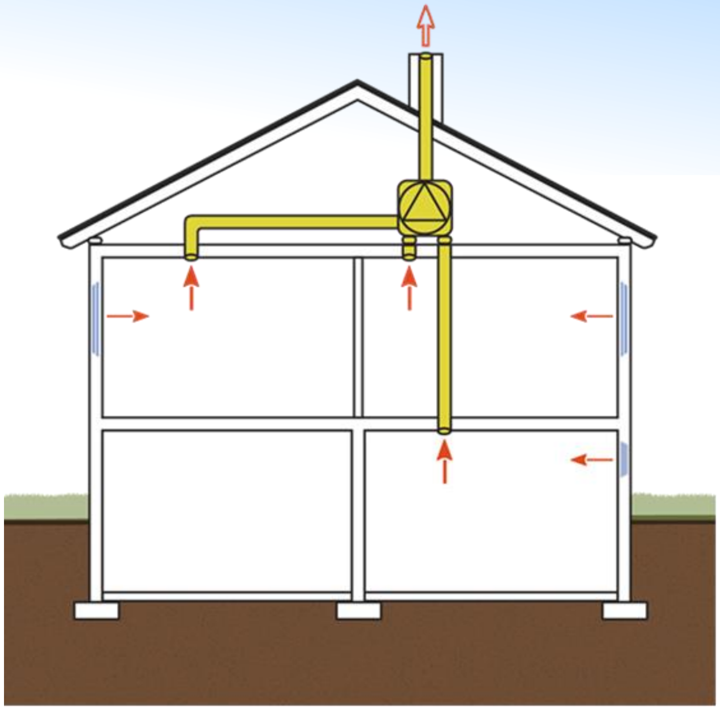
Natural draught ventilation

- Works better in cold climates due to higher temperature differences between the inside and the outside of the building.
- Usually not possible to reduce the radon levels to a specified level (e.g. below reference level) by natural ventilation alone.
- A far higher air exchange rate would be needed to solve a radon problem



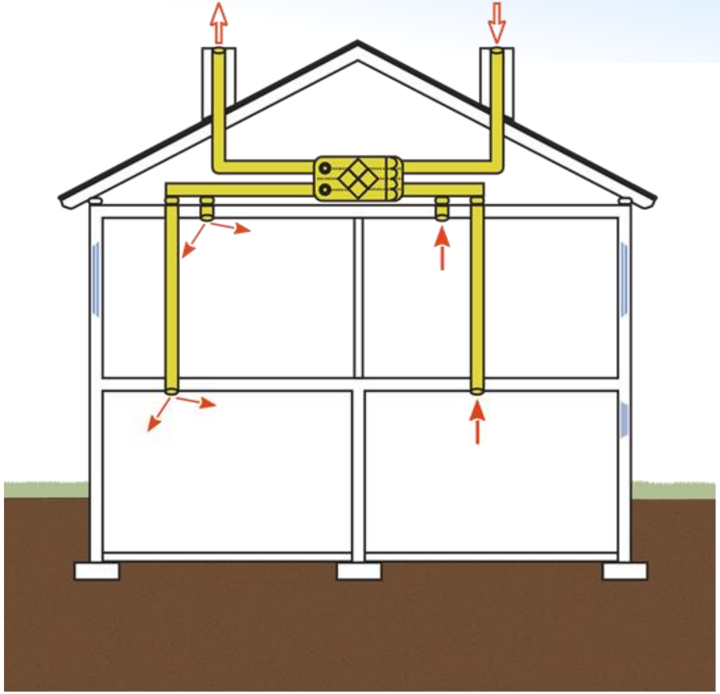
Mechanical exhaust air ventilation system

- Rate of air change is determined by: fan, area of ventilation opening, and airtightness of the building.
- Less affected by: density difference between indoor and outdoor air and influence of wind.
- Find and seal all cracks and leaks in the floor construction and, if needed, also install a soil depressurization solution.
- Mechanical extraction of air from the building results in the building being underpressurized compared to the external air, and also compared to the soil gases that contain radon.
- Pressure difference between the soil and the inside of the building **draws the soil gases towards the inside of the building.**
- Need to be carefully balanced not increase the radon problem from the ground.
- If radon source is construction material - solution can include installing a mechanical exhaust air ventilation system. However secondary effects: increased ventilation - heat losses, which may be unacceptable in cold climates.



Mechanical supply and exhaust air ventilation system

- Air change rate is determined by the balance between air supply and exhaust airflow rates (also known as an air-to-air exchanger or a heat recovery ventilator)
- Compared to two previous systems has a better ability to control and balance the movement of air through the building.
- Well-balanced - Less influence from the weather, such as external air temperature and wind.
- Unbalanced system - may induce ingress of radon from the soil into the building and lead to elevated radon levels.
- Normally enough capacity to solve an existing radon problem due to exhalation of radon from building and construction materials.
- However, if designed for high degree of energy efficiency may not have sufficient spare capacity to allow for increased airflows necessary to reduce indoor radon levels.
- If radon source is soil air - may be enough to adjust the system with a slight overpressure in the building to reduce the ingress of radon.
- However, in very cold climates - care needs to be taken to prevent internal moist, as it may condense and could freeze.
- For larger multi-zone buildings, it may be difficult to control and balance airflows, involves greater cost with electrically controllable exhaust and inlet vents and the need for a sophisticated building management system.
- Systems may be appropriate for individual houses but not for larger buildings.
- **Find and seal** all significant cracks and leaks in the floor construction!



Radon exhalation from construction materials (I)

Exercise: Calculate contribution of radon into indoor air from construction materials:

$$C_{bm} = \frac{1}{(\lambda+n).V}.\sum_i E_i.A_i$$

where

- C_{bm} = Radon contribution to indoor air concentration from construction material
- λ = Radon decay constant = 0.00755
- n = Air exchange rate = 0.5 volumes/hour
- V = Room or buildings inner volume = 30 m^3
- E_i = Radon exhalation rate = 13 Bq/m^2h*
- A_i = Surface area of walls made using the construction material in the room = 55.4 m^2

* The radon exhalation from concrete is assumed to be 13 Bq/m^2h for this exercise, which was obtained empirically and is typical for untreated concrete surfaces, for construction materials with an activity concentration of about 60 Bq/kg of Ra

Radon exhalation from construction materials (II)

The contribution of the construction material to the radon concentration in the room:

- Ventilation rate is 0.5 air change per hour, is a typical exchange rate for some workplaces and dwellings.

$$C_{bm} = (1/((0.00755 + 0.5) * 30)) * (13 * 55.4) = 50\ \text{Bq/m}^3$$

- For workplaces and municipal buildings, the airflow demands are typically higher, up to 1.0 air change per hour:

$$C_{bm} = (1/((0.00755 + 1) * 30)) * (13 * 55.4) = 25\ \text{Bq/m}^3$$

- Knowing the contribution of building and construction materials to indoor radon concentrations is important in areas of the world with more stringent building codes.
- Some sustainable building standards necessitate very low radon concentrations in newly constructed buildings.
- If radon contribution from building and construction materials are not accounted for – the compliance to these standards may fail.
- Building designer must have a knowledge of the radium content of the building and construction materials to be able to control the uranium and radium contents of the aggregate (ballast) used in the concrete for such buildings.

Steps of radon mitigation work

DIAGNOSTIC AND INVESTIGATION

- Data about the building

- Diagnostic measurement

DESIGN AND IMPLEMENTATION

EFFICIENCY ASSESSMENT

OPERATION AND MAINTANENCE

Data about the building

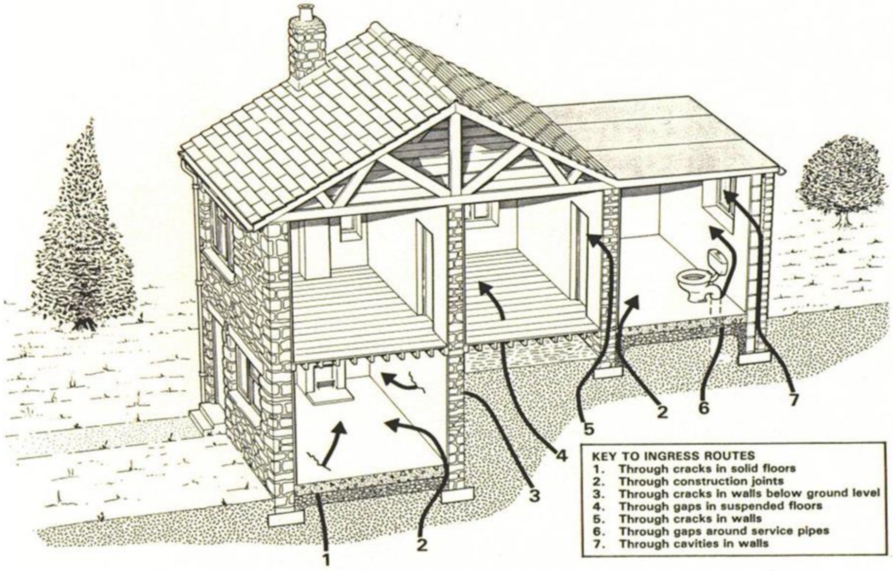
- General information (Location, climate, ground characteristics etc)
- General description (terrain, building following the terrain, use of building, general footprint shape, approximate height of the building)
- Description of floors, number of underground floors, total estimated footprint area
- Description of the building's load bearing structure, depth of foundation walls in the ground, and material used for the foundation walls
- Definition of internal floor footprint areas within foundation walls
- Description of the expected underlaying layers, identification of the air permeable layer, pathways due to settling of fill material and utility installation.
- Description of sealing of the floor structure to the internal and external walls, gap width between floor and internal/external walls, and materials of the floor and walls need to be noted
- Year (or period) of construction and possible renovations, extensions to the original building, any natural events that occurred since construction
- Estimated or measured airtightness, description of windows and external doors
- Location of the tunnels for utilities, whether closed at their ends, whether made of continuous material or made of modular elements with joints
- Location of the sewage pipes
- Location of the air exhaust or air supply vents

Diagnostic measurements

- Might be needed to understand the entry points of radon into building and the volume of soil air entering the building.

Radon Entry points:

- Concrete slab foundation;
- Basement;
- Crawl space.



Radon entry points (reproduced with permission of IHS Markit)

How much air comes from the ground beneeth?

If indoor radon data and soil radon data are known, possible to calculate how much soil air enters the building from the ground every hour:

$$C_{house} = \frac{1}{(\lambda + n) * V} * C_{soil} * L$$

where

C_house = Measured radon concentration in the house (Bq/m3)

C_soil = Measured radon concentration in the ground under the building (Bq/m3)

λ = Radon decay constant

V = Volume of air in the house (m3)

n = Air exchange rate (air exchange/h)

L = Volume of soil air entering the building per hour (m3/h)

Examples

Example 1. Assume the following parameters for the building:

- Measured radon concentration in the house (Chouse) - 500 Bq/m3
- Air volume of a house (V) - 500 m3
- Air exchange rate ACH (n) - 0.5/h
- Measured radon concentration in soil under the building (Csoil) - 2 000 Bq/m3
- Radon decay constant λ - 0.00755

$$L = ((C\_house)\cdot(\lambda+n)\cdot V)/C\_soil$$

$$L = (500 * (0.00755 + 0.5) * 500) / 2\,000 = 63.4 \text{ m3/h}$$

63.4 m3/h - is a lot of air, and one major entry point is causing this large amount of soil air to entry to the building.

Example 2: All parameter values are the same as in example 1, except for C_soil:

- C_soil = 40 000 Bq/m3

$$L = ((C\_house)\cdot(\lambda+n)\cdot V)/C\_soil$$

$$L = (500 * (0.00755 + 0.5) * 500) / 40\,000 = 3.2 \text{ m3/h}$$

The challenge - to find the leakage spot or spots where a flow of only 3.2 m3/h enters the building.

Additional investigations

Thermography

- Can be a very useful tool in investigating leakage spots especially in colder climate countries
- Camera image gives a hint on where to perform the radon “sniffing”.
- Saves time and allows to avoid an unnecessary use of the radon instruments.

Blower door test

- Can be used to establish the airtightness of a building
- Involves fitting a temporary fan and frame into the entrance door, blowing air into (pressurizing) or drawing air out of (depressurizing) the closed building.
- By using tracer smoke - can visually see smoke passing through gaps in the structure.

Radon “sniffer”

- To support the previous methods to confirm/identify important radon entry routes
- OBS! interpretation of results can prove difficult if individual areas of the building cannot be isolated.
- Radon measurements by *sniffer* detectors will be affected by the weather

Once a radon professional gains experience with visual surveys of buildings, and increase their understanding of building construction techniques, they need to rely less on the use of a radon sniffer detector.

Radon mitigation methods

Start with sealing combined with:

- Depressurization of the soil
- Pressurization of building
- Mitigation of Radon emitted from construction materials

Depressurization of the soil (I)

- Basic principle - pressure difference between the soil and the building is always negative.
- Depressurization of the soil - is deemed to be most robust and successful compared to other approaches.
- Might increase heat losses from the building and proper system design is needed (i.e. minimizing necessary airflow from the soil to the outside).
- Necessitates the use of a fan, consuming electrical power - proper design, the consumed power can be kept well below 1 to 5 kWh/day.
- Passive depressurization is prone to many different factors affecting its effectiveness.
- Passive systems always have to be designed in such a way that adaptation to an active system is possible and simple.

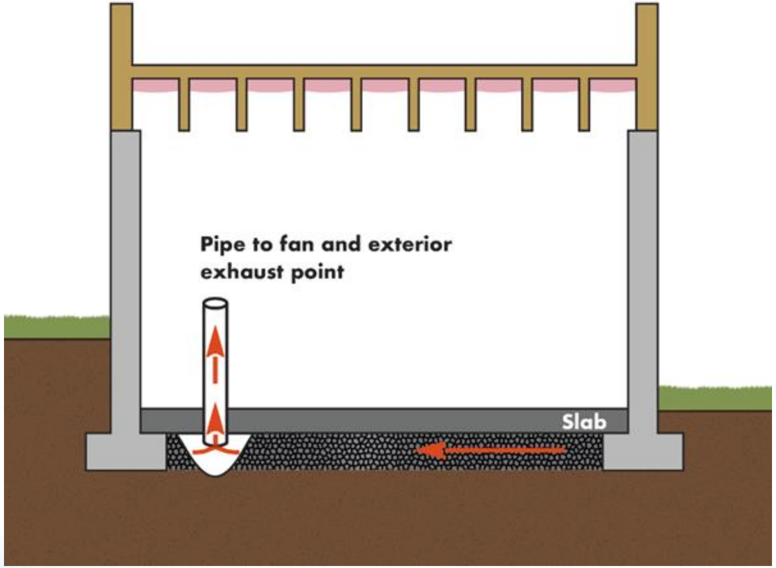
Depressurization of the soil (II)

Active soil depressurization (ASD) consists of the following elements:
- Permeable layer;
- Suction point(s);
- Exhaust;
- Sealing;
- Fan;
- Operation and monitoring system.

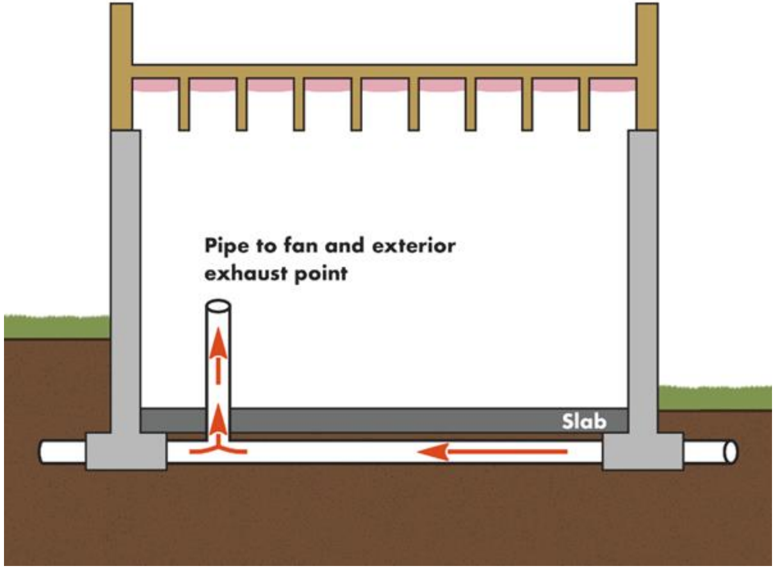
ASD system may have several different configurations:
- **Sub-slab depressurization (SSD);**
- **Drain-tile depressurization (DTD).**

The basic approach of the SSD and DTD systems is to create negative pressure under the existing ground concrete slab(s).

ASD: Sub-slab depressurization (SSD)



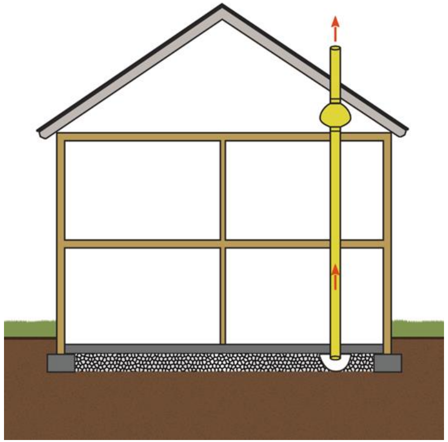
Sub-slab depressurization system. Copyright 2020 AARST.

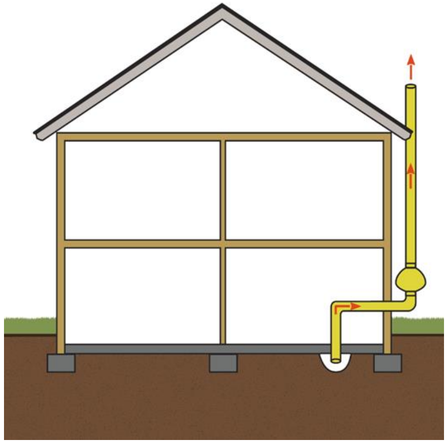


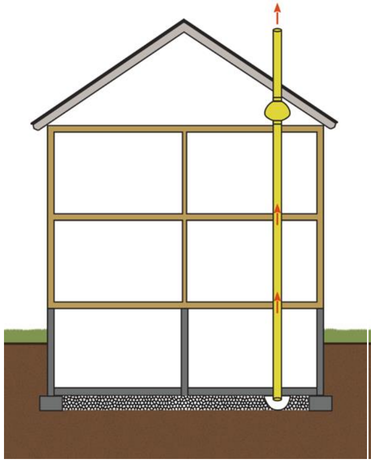
Drain-tile system. Copyright 2020 AARST.

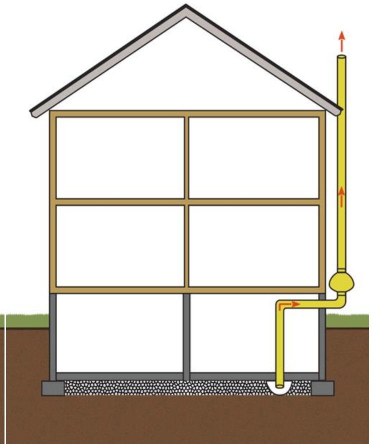
ASD: Drain-tile depressurization (DTD)

The fan is intended to induce the pressure difference in the system.









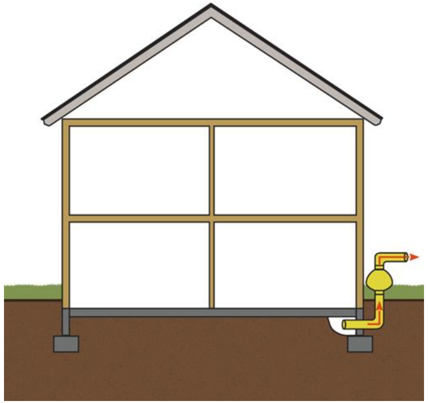
Sub-slab depressurization with internal fan in ceiling and roof level exhaust.

Sub-slab depressurization with fan external to building and roof level exhaust

Sub-slab depressurization with internal fan in ceiling and roof level exhaust from building with basement.

Sub-slab depressurization with fan external to building and roof level exhaust from basement.

ASD: Drain-tile depressurization (DTD)



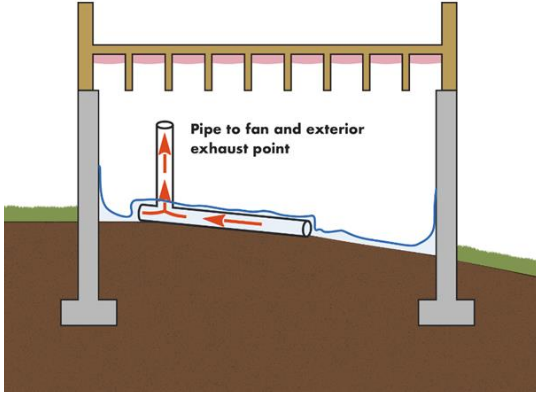
External sub-slab depressurization low level exhaust

With smaller buildings it is possible to core drill through the foundation to form a suction point at the edge of the floor and connect it to a fan with a low level exhaust.

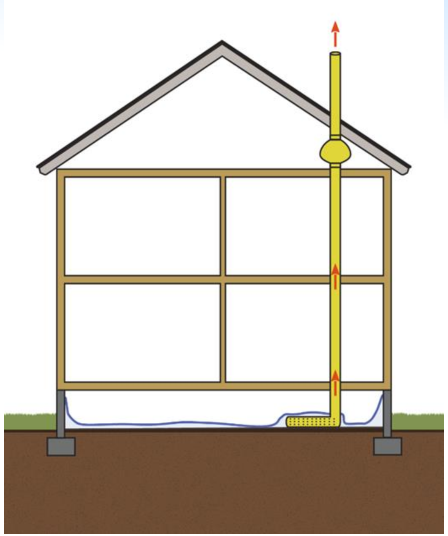
The exhaust outlet has to be located where it will not be a nuisance.

OBS! strongly advised to measure radon in the living areas adjacent to the exhaust location to determine if radon is re-entering the building.

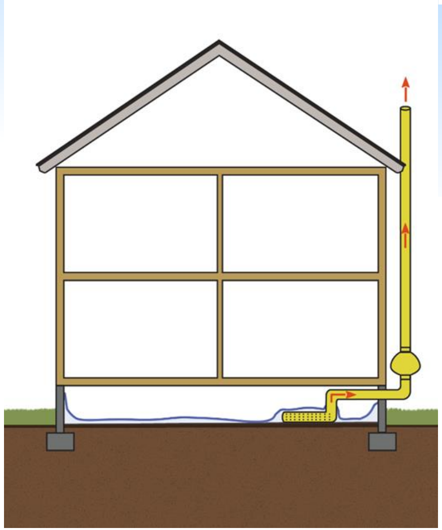
ASD: Sub membrane depressurization (SMD)



Sub-membrane depressurization.



Sub-membrane depressurization with internal fan and roof level exhaust.



Sub-membrane depressurization with external fan roof level exhaust

The SMD system consists of the following elements:

- Membrane;
- Permeable layer;
- Suction point;
- Perforated pipe and suction pipe;
- Sealing;
- Exhaust;
- Fan;
- Operation and monitoring system.

Basic approach - create negative pressure under a membrane.

Used in cases where there is either no slab on the ground or the upper layer of the ground is permeable to an extent that prevents effective pressure field extension.

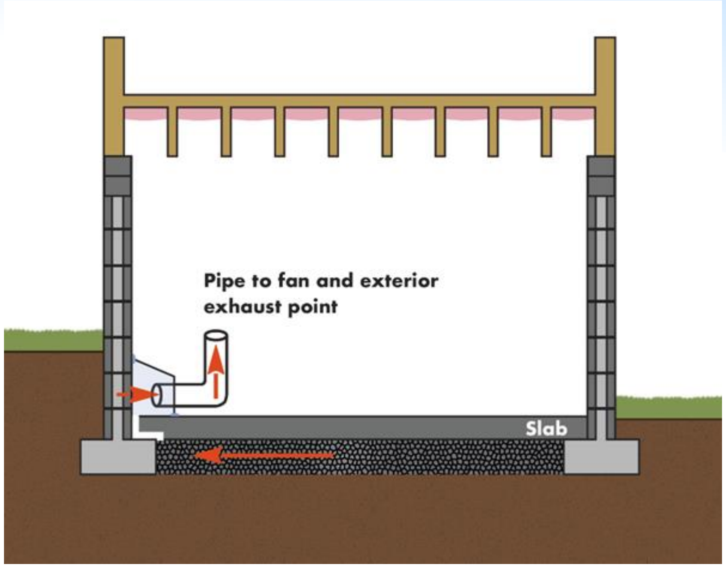
Also used in mitigating radon in buildings with crawl spaces.

ASD: Baseboard depressurization system (BBD)

The BBD system consists of the following elements:

- Radon collection;
- Suction point;
- Piping;
- Sealing;
- Fan;
- Exhaust;
- Operation and monitoring system

Basic approach - creation of negative pressure in the cavity running along the inside perimeter of the concrete slab floor.

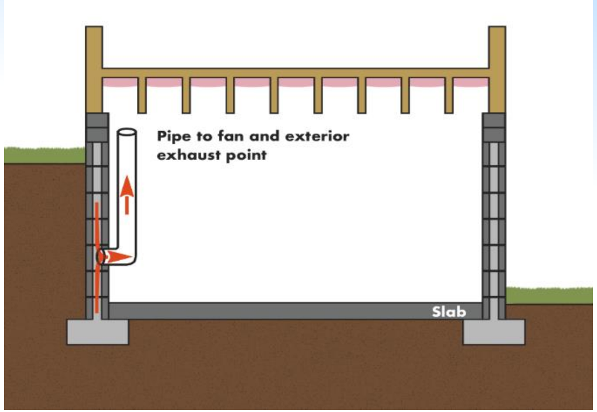


Baseboard depressurization. Copyright 2020 AARST.

ASD: Block Wall Depressurization (BWD)

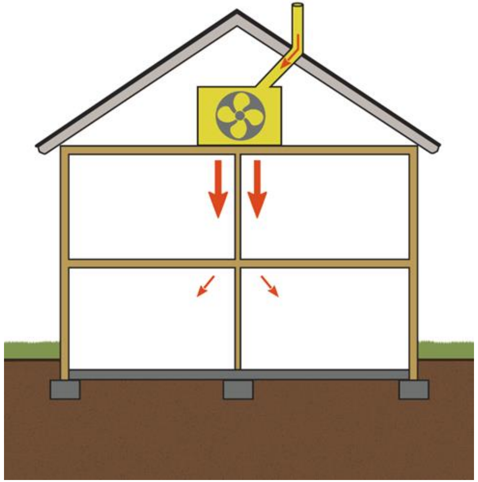
The BWD system consists of the following elements:
- Radon collection;
- Suction point;
- Piping;
- Sealing;
- Fan;
- Exhaust;
- Operation and monitoring system.

Basic approach - creation of negative pressure in the block walls installed as the basement foundation walls.

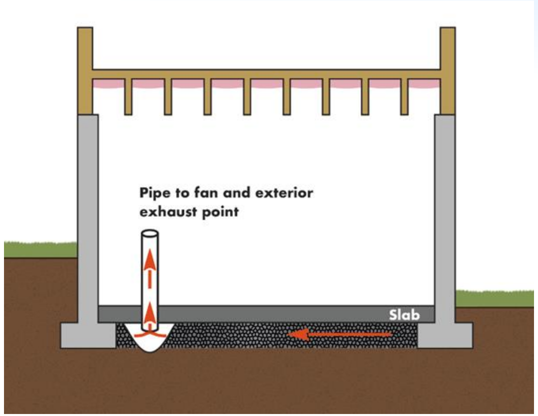


Block wall depressurization. Copyright 2020 AARST.

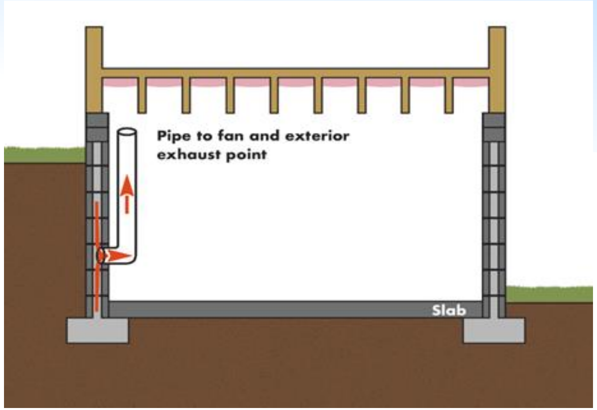
Building pressurization (I) – Positive ventilation, SSP and BWP



Positive ventilation unit

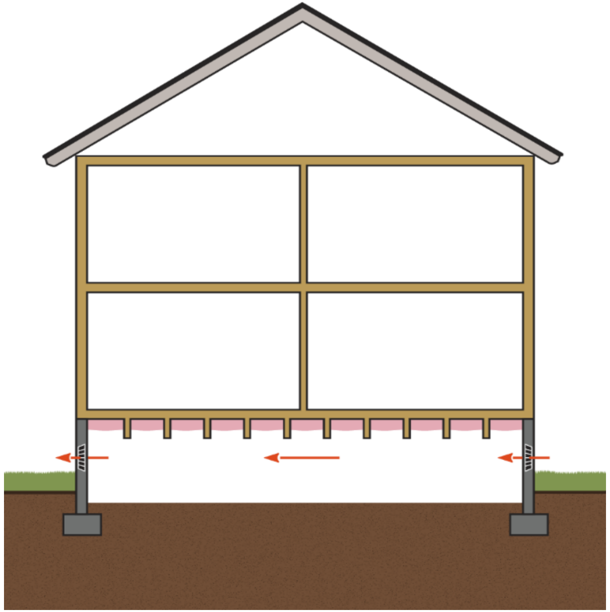


Sub-slab pressurization (SSP)
Sub-slab pressurization is essentially the same system as the SSD system, but the direction of the airflow is reversed.



Block wall pressurization (BWP) system is essentially the same as the BWD system, except the airflows are reversed.
Air supply is usually from the external outdoor air.
If internal air is used, care needs to be taken so as not to under pressurize some rooms in the building, as this could cause suction of radon rich air from under the building into these rooms.
If external air is used, care needs to be taken so as not to excessively cool the concrete block wall.

Building pressurization (II) – Crawl space ventilation



Crawl space ventilation.

- Basic approach - either to ventilate the crawl space, or to install a sub-membrane depressurization (SMD) system
- Where radon levels are only just above reference level - the first step is to ensure that the crawl space is adequately ventilated
- Original ventilation grilles may have become obstructed over time
- The building may sometimes need additional ventilation grilles
- If the building has a timber floor, all significant gaps and cracks in the floor need to be sealed. Do not use impermeable membrane, as it could result in some of the timber floor rotting
- Where radon levels are significantly above reference level - crawl space can be ventilated using a fan (operating in positive or negative pressure)
- Fan may have an adverse impact on indoor comfort, particularly during winter. Crawl space ventilation will alter temperatures in the crawl space - consider sufficient thermal protection of the structure.
- Add thermal insulation of substantial thickness to the underside of the floor and to service pipes if needed

Rn emitted from construction materials

- Removal or replacement of the construction material containing elevated levels of ^{226}Ra - a preferred option if it is possible to access the material (such as removal of internal decorative stone panels).
- If the material is embedded within the building structure (concrete foundation or structural framing) - this method is unlikely to be either a practical or an economical option.
- Ventilation of affected parts of the building;
- Ventilation between the layers of construction materials;
- Ventilation of the whole building.

Radon from household water

Calculation of radon exhalation from the water into a building

$$C_v = \frac{C_w}{24\,.\,(\lambda + n)\,.\,V} \sum_i e_i\,.\,W_i$$

- C_v = Radon contribution from household water usage to indoor air, Bq/m^3
- C_w = Radon concentration in the water, Bq/m^3
- λ = Radon decay constant, 0.00755 h^{-1}
- n = Air exchange in the building, h^{-1}
- V = Building volume, m^3

- W_i = Volume of water used daily for purposes, m^3/day
- e_i = Share of radon that merges into the indoor air

Radon emanatin from different water applications

Use (i)	Radon emanation to indoor air (e_i), %
Shower	60–70
Bath	30–50
WC	30
Laundry	90–95
Dishwashing	95
Drinking water	10–45

Solution: water aeration system of at least 200 liters.

OBS! Placement of the aeratin system!

Efficiency assessment

- *Use reliable professionals*
  - radon professional associations - support promotion of good practices and regulate the professional market,
  - contract for radon mitigation or prevention work - set of guarantees for the effectiveness of work,
  - customer must have opportunity to claim corrective actions at the builder's expense in case the mitigation work does not meet the agreed results.
- *Post-mitigation radon measurement (same points)*
- *Post-mitigation system checks*
- *Information for the occupier, owner, building manager*

Information on system operation

Provide the following information to the building occupier, owner or building manager, as appropriate:

- A brief description of radon and health risks. This note could also contain clarification on why the mitigation has been carried out and why it needs to continue to work.
- Location of the pre-mitigation and post-mitigation radon measurement points for any future measurements.
- Description and drawings with demonstration of the installed mitigation system and description of how it works.
- Specification of the entire system, blueprints and equipment manufacturers details.
- Detailed description of what needs to be checked by the occupier, owner or building manager in order to know whether the system is working (i.e. fans are operating), and the frequency of the checks.
- Records of all measurement made of the system (e.g. pressure, electricity consumption), dates and readings.
- Recommended frequency of radon measurements to demonstrate that the system is continuing to adequately reduce radon levels in the building.
- Radon mitigation professional contact details.
- National radon guidance, and the contact details of national authority, if available.

Guess Rn activity concentration and Rn source

Do not guess – make proper diagnostic assessment!

Closing

RER 9153 plan for 2020

- RW on regulatory control of radon in workplaces. Completed in Hungary, 14-17 January 2020 EVT1904538
- EM to Romania to support improvement of national action plan. Completed 12-13 February 2020 EVT1807178
- SRW for building professionals to share best practices for reducing concentrations in buildings (15 participants, 2 IEXs, 5 days), 2021; for Russian speaking countries, Planned 2020, postponed to 2021 EVT1807179
- RTC on radon remediation for building professionals, Planned in Croatia 2020, postponed to 2021 EVT1907202
- RWS meeting of the STEAM project group for next step planning Planned virtual 15-17 December, 2020 EVT1907199
- SRW for good laboratory practice in the measurement of radon and Inter-comparison exercise for passive measurements and QA in measurement of radon. Planned virtual in France 24-27 November, 2020 EVT1907201
- EM to Portugal to support development of RAP. Completed virtual 6-8 October, 2020 EVT1907203
- EM to support Member State on elaboration of radon action plan (2 IEXs, 2 days), Planned in Uzbekistan Q4 2020, postponed
- Procurement of passive detectors. Countries: Romania, Slovakia

RER 9153 plan for 2021

- TRC for implementation of protocols and procedures of radon measurement in dwelling, workplaces and water. Planned in Slovakia 19-22 January, 2021 EVT1907200
- SRW for good laboratory practice in the measurement of radon and Inter-comparison exercise for active measurements and QA in measurement of radon (15 participants, 2 IEXs, 3 days), 2021 (venue TBD by TO)
- RWS on identification of workplaces, graded approach and optimization of protection in workplaces, health risk assessment methods (33 participants, 2 IEXs, TO and PMO, 5 days), 2021 Q4, Greece
- RWS on protection against radon in workplaces (work safety authorities, occupational health, health professionals and HSE), 2021 Romania
- SRW for building professionals to share best practices for reducing concentrations in buildings (15 participants, 2 IEXs, 5 days), 2021; for Russian speaking countries, Planned 2020, postponed to 2021 EVT1807179
- RTC on radon remediation for building professionals, Planned in Croatia 2020, postponed to 2021 EVT1907202
- Procurement of passive detectors
- EM to member state XX
- RER9153 project final assessment and STEAM project finalisation Q4 .

Scope and objective

Have these objectives been achieved?

- Provide expert advice on development and implementation of Radon Action Plan
- Objectives:
  - to present international requirements and experiences from UK and Spain on the elements of national Radon Action Plan (RAP)
  - to present Portuguese experience and challenges in implementation of the requirements
  - to discuss possible ways forward, roles and responsibilities in development and implementation of RAP.

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Thank you!