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CRAWL SPACE: HOW TO AVOID MOISTURE AND SOIL GAS PROBLEMS

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CANADA MORTGAGE AND HOUSING CORPORATION

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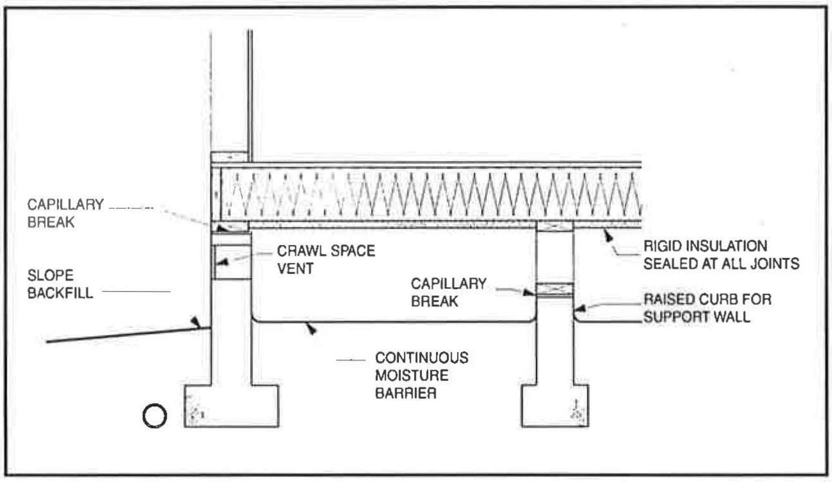

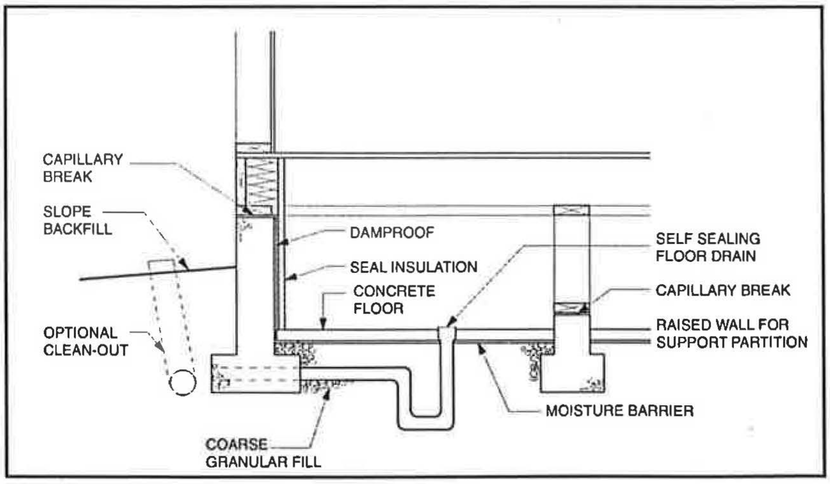

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Crawl Spaces: how to avoid moisture and soil gas problems

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CRAWL SPACE FOUNDATIONS

Introduction

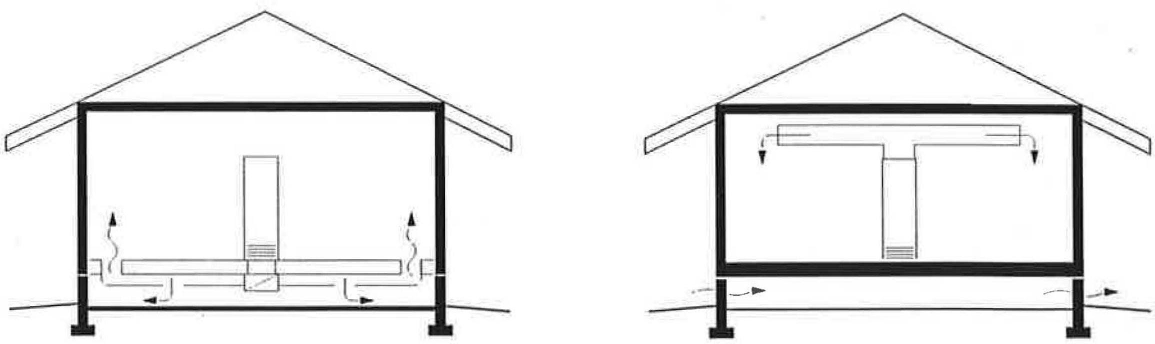
A crawl space is a type of shallow foundation, usually with the floor at grade and with a low headroom, typically less than 4 feet. Crawl spaces are commonly used in areas where there is a high water table, or where services are shallow (as in milder climate zones). They can also be found where deep excavation is not needed to provide adequate structural support, where the frost line is shallow, or where ground conditions are inappropriate for full in-ground basements – for example where there is considerable bedrock near the surface.

Crawl spaces often do not get adequate inspections and there is a general lack of appreciation by the housing industry for the elements that make up an effective moisture control strategy.

Moisture-related problems occur in many crawl spaces despite the fact that building codes require vents. Crawl space moisture needs to be controlled because it can result in mold growth and decay in the crawl space lumber, if humidity levels are too high. Moisture from the crawl space can also move into the living area, or even into the attic, causing similar problems in these areas.

The connection of crawl space air to the rest of the house can be affected by the choice of heating and cooling systems. With a forced warm air heating system, the crawl space is usually linked to the rest of the house through the leaky ducts placed in the crawl space. This provides plenty of mixing of crawl space air with the rest of the house, so the moisture is dissipated throughout the house. In houses without forced air systems, the house interior is not affected as much, because there is less physical connection between the house and the crawl space. Houses with high levels of air leakiness will move crawl space air into the house regardless of the type of heating system.

Figure 1: Crawl Spaces



CONDITIONED
CRAWL SPACE

UNCONDITIONED
CRAWL SPACE

FIG.1

Many problems found in crawl spaces are related to a misunderstanding of how crawl spaces work. The insulation, air and vapour barriers are typically not well integrated with the rest of the house. Many crawl spaces are built over an exposed dirt floor, rather than incorporating a ground cover, floor drain and perimeter drainage similar to a properly constructed basement.

Recent research has illustrated alternative crawl space construction techniques. Passive ventilation may often be unnecessary or ineffective. The purpose of this publication is to explain the latest understanding of crawl spaces, and how they should be built to avoid problems.

Classification of crawl spaces

Essentially, there are two types of crawl spaces: conditioned and unconditioned. The National Building Code of Canada has recognized this distinction by incorporating requirements based on whether the crawl space is heated or not heated. Understanding the background behind the two approaches will make it easier to design for trouble-free construction.

Conditioned, or heated crawl spaces, are those spaces that are not separated from heated/conditioned portions of the house. The crawl space temperature may be different from the main body of the house, but the space is still connected to the house air. Construction should be treated as if it were a shallow basement. If ducts and plumbing runs are placed in the crawl space, they may not require special sealing and thermal insulation protection. The crawl space will be heated, cooled and ventilated as it is for an interior basement space. The air barrier, vapour barrier and insulation details should be similar to standard above and below grade construction for the location. The crawl space floor should also incorporate a vapour barrier and floor drain.

Unconditioned, or unheated crawl spaces, are separated from the heated/conditioned portions of a house. This type of crawl space is essentially exterior space, so that the floor construction above it must be treated as the bottom of the building envelope. The floor above should incorporate the air barrier, vapour barrier and insulation appropriate for the location. The unconditioned crawl space should be vented to the exterior, and house services through the crawl space should be avoided. The code specifies a minimum amount of vent area required, however, the optimum amount is dependent on local climatic conditions. Any ducts or other services that must be placed in the crawl space need to be carefully detailed to ensure that air and vapour barriers are maintained and adequate thermal insulation is provided. However, in general it is best to avoid putting ductwork in unconditioned crawl spaces.

Although the unconditioned crawl space is isolated from the conditioned space of the house, following moisture control procedures is still prudent. This will avoid undue moisture concentrations that could still create problems for the construction.

Building Science Principles

Trouble-free construction requires an understanding of heat, moisture and air flows into and out of the crawl space.

Moisture

Forms of water that are of concern in crawl spaces are bulk water (such as ground and rain water), liquid water manifested through capillary action, and water vapour. The source and consequences of bulk water are well understood. Whether the crawl space is conditioned or unconditioned, bulk water entry (such as flooding or leakage during snow melting) is usually highly visible and must be avoided.

Capillary action causes liquid water to rise up thin tubes, such as the pores in concrete and other masonry materials. These enable ground water to rise through the material into the crawl space. Capillary action can be stopped by sealing the pores to prevent water entry, blocking the movement with dampproofing material, or making the pores large enough to avoid water entry.

The effect of water vapour is less well understood. The source may be ground water that evaporates directly into the crawl space if there is no moisture-resistant ground cover, or water that moves by capillary action and evaporates into the space. A concrete ground cover by itself, without a moisture barrier, may not be enough to control ground water migration, as water can wick up through the concrete by capillary action.

The second source of water vapour is ambient moisture from the air – moisture-laden, outside air entering the crawl space by ventilation. Warm air in summer can carry a large amount of moisture. Successful operation of a crawl space requires an understanding of the factors affecting water vapour.

Measures to prevent bulk water problems

Bulk water may be rain water or rising ground water. Design principles for crawl space construction to avoid water problems apply equally to conditioned and non-conditioned basements and crawl spaces.

Where water tables are known to be high, the crawl space floor should be set above the water table level. Site conditions should be investigated to assess drainage requirements. Backfill should always be graded to create a small slope away from the house so that rain run-off is diverted away from the foundation. Perimeter drainage tiles should be designed for easy testing. It may be worthwhile to add clean-outs to make cleaning easier if silting does happen, especially in areas with high rainfall. Flexible foundation drain pipes are inexpensive but can be crushed or damaged by improper backfilling. Because of this, a rigid pipe system offers some advantages.

A drain from the granular layer beneath the slab through the footing to the foundation drain tile should be provided. This allows any water that may accumulate under the crawl space floor to drain into the perimeter drain system. Fine granular sand often used under slabs does not provide an effective capillary break. A coarse granular fill (20 mm or 3/4 inch nominal diameter) does a much better job.

High ground moisture levels can affect any wood structural elements directly in contact with concrete. Interior support walls sitting on a footing that is flush with the crawl space floor can absorb ground moisture. Moisture moving through the footing and slab can saturate the sill plate, even if it sits on an asphalt impregnated paper or foam gasket. Moisture contents as high as 30% have been measured in plates sitting flush with the floor. Field tests showed that a support wall resting on a low concrete curb wall (50 to 100 mm above the floor), with a capillary break, did not experience such high moisture contents.

Water vapour

Water vapour is always present in ambient air. The amount will vary depending on the source of water and environmental conditions in the immediate area. A review of the physics involved will make it easier to understand better how moisture conditions change, and why they can create problems.

There is a limit to how much water vapour can remain mixed with dry air at any given temperature. When the limit is reached, the air is said to be saturated. At this point, the air is at 100% relative humidity. As air temperature increases, it can hold a greater absolute amount of water vapour. As the air cools, it can hold less.

Absolute moisture quantities can be significant. Saturated air at 20°C (in other words at 100% relative humidity) can hold about 15 grams of moisture for every one kg of dry air, and at 30°C it can hold 27 grams.

Figure 2: Moisture Content of Air at Different Temperatures

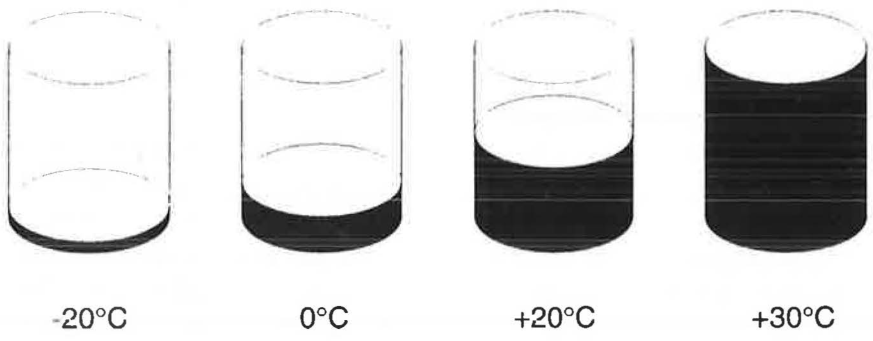


FIG.2 MOISTURE CONTENT OF AIR AT DIFFERENT TEMPERATURES.

However, at 0°C, one kg of dry air can hold only about 3.7 grams of moisture, and at – 20°C it is about 0.6 grams of moisture.

When saturated air is cooled, it sheds its excess moisture. Moisture in the air condenses on any cool surface in the immediate area once the dew point is reached. That is why, as temperatures fall, cold surfaces that are at or below the dew point temperature become wet with condensation. For air at 20°C and 50% relative humidity, the dew point is 12°C, so there will be condensation on surfaces whose temperature is 12°C or less.

Consider a 100 m² crawl space that is one metre high. It contains about 120 kg of air. If the air is originally at 20°C and 50%, and is cooled to 5°C, and assuming there is no new moisture entering the space, about 1.2 litres of water will condense on the coldest surfaces. If the moisture source is not isolated, the water will continue to enter and condense in the space.

Crawl space moisture is not just a problem in temperate climates. A study in northern Manitoba found that vents opened in the spring, meant to dry out the crawl space, actually increased crawl space moisture levels. This happened because the summer outdoor air can be warm and humid, even in northern climates, but the crawl space walls and other structural elements were still cold.

Soil Gases

A variety of gases are present in the soil. The two principal ones of concern are radon and methane.

Radon is a colourless and odourless radioactive gas formed by the natural decay of radium. It is present in soil, rock and ground water in varying concentrations in many parts of the world. As radon normally enters the building from the surrounding soil, the concentration of gas is usually highest in the foundation area.

A crawl space study in California found that as much as 50% of the radon gas released into the crawl space will enter the living space. While the focus was on radon infiltration, the results are also valid for water vapour moisture entry and for other types of soil gases.

Methane is the principal gas resulting from the decay of organic material in the soil. Houses would not normally be built on organic soils, but in some circumstances there may be significant organic content in the soil or migration from nearby landfills.

If the crawl space is conditioned, the main method of dealing with radon and other soil gases is by preventing gas entry. This is done by carefully sealing the house foundation from the soil.

If the crawl space is unconditioned, a properly detailed first floor air barrier assembly will prevent excessive soil gas entry into the house (see Section 7.4 of *Canadian Home Builders Association Builders Manual*).

Heat/temperature flows

Heat flows from a warm area to a cooler area. Warm air rises by convective air movement. The greater the temperature difference, the greater the driving force to move the air.

During the coldest weather, in cold climates, stack effects cause air to be drawn into the lower parts of the house, where the air replaces warm air exfiltrating through the upper portions of the house. In a heated crawl space, this will encourage crawl-space-to-house ventilation, and will usually encourage drying. However, stack effect induced pressure differences can also draw in soil gasses unless the crawl space floor is well sealed.

Radiation and leakage from duct work in a typical, insulated, forced-air heated house crawl space are often enough heat to keep the crawl space at 15°C, even at outside temperatures of – 10°C.

Both stack effects and pressures induced by duct leakage will affect the crawl space air. Stack effects will tend to draw crawl space air into a house from an unconditioned crawl space. As this air may contain soil gasses and moisture and will be cold, the floor above the crawl space must be well sealed to prevent air infiltration.

Ventilation

Vents are installed in crawl space walls to provide openings for passive ventilation. These vents are often louvered and screened. Some can be manually closed. Vents have long been considered an effective defence against moisture buildup in crawl spaces and as a means of ensuring adequate drying during the non-heating season. The use of crawl space vents has been an attempt to compensate for inadequate or ineffective drainage systems and moisture barriers. However, despite the use of crawl space vents as required by building codes, crawl spaces often have high moisture levels that can result in high humidity and condensation in living areas.

The presence of passive vents in crawl spaces does not guarantee ventilation. The vents are close to the ground where they are typically well sheltered from winds. The vents are often inoperable because sunlight has distorted them, they have been installed poorly, or they are blocked by building material or vegetation. Crawl space vents are incompatible with conditioned crawl spaces where forced air heating is used. The vents (especially those left open in the winter) can operate like warm air registers, moving warm air to the outside. They can be the single most important reason for excess air leakage and heat loss from houses.

Unfortunately, most home owners are not aware that vents provide a drying influence only part of the time. The most direct way to measure the effect of vents is to monitor the crawl space relative humidity, and to observe whether it increases or decreases with the opening of vents. Monitoring has to be repeated frequently due to weather variations, and most householders will not want to operate vents if this level of monitoring is required.

For example, in a warm humid climate, temperatures of 30°C and relative humidity of 70-80% are common. However, crawl space temperatures at this time could easily be less than 20°C. Since cooler air cannot hold as much moisture, there will be condensation. (The dew point temperature of air at 30°C and relative humidity of 70-80% is 24°C).

Research by various agencies in North America has found that a reasonably effective moisture barrier was adequate to control moisture without any crawl space ventilation with outside air.

How to build a trouble-free crawl space

A checklist for things to consider at the design and construction stages:

Determine whether the crawl space is conditioned (heated). The National Building Code of Canada considers a crawl space to be heated if the crawl space contains heating ducts that are not sealed and insulated; if the crawl space is not separated from the conditioned space of the house; or is used as a hot air plenum.

1. Manage rain and ground water

Ground water must be managed no matter whether the space is conditioned or not. This applies for both conditioned and unconditioned crawl spaces:

- Assess drainage requirements, especially where water tables are high.
- Grade backfill to create a slope away from the house so that rain run-off is diverted away from the foundation.
- Install adequately sized perimeter drainage system.
- Consider providing clean-outs for foundation drainage systems to provide easy maintenance.

2. For conditioned crawl spaces:

- Install a moisture barrier on the soil. If a concrete skim coat is being used, ensure a poly sheet is installed over the ground to provide a complete soil cover. Sealing the poly at the edge is not crucial, but it should be free of puncture holes.

Figure 3: Conditioned Crawl Space

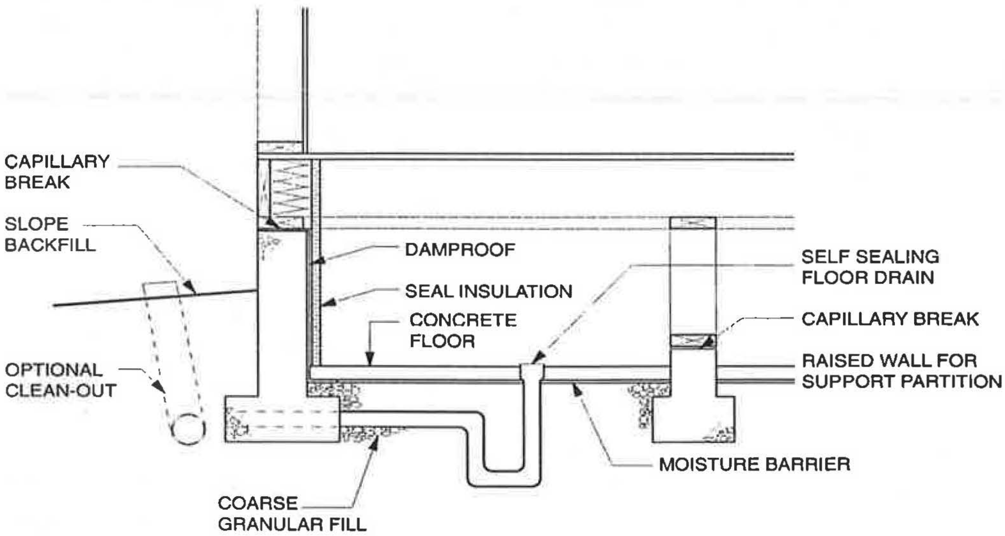


FIG.3 CONDITIONED CRAWL SPACE

- EXTERIOR VENTILATION NOT REQUIRED
- SPACE IS CONDITIONED BY HOUSE HEATING AND VENTILATING SYSTEMS
- INSULATION OF WALLS CAN BE OUTSIDE OR INSIDE

Figure 4: Unconditioned Crawl Space

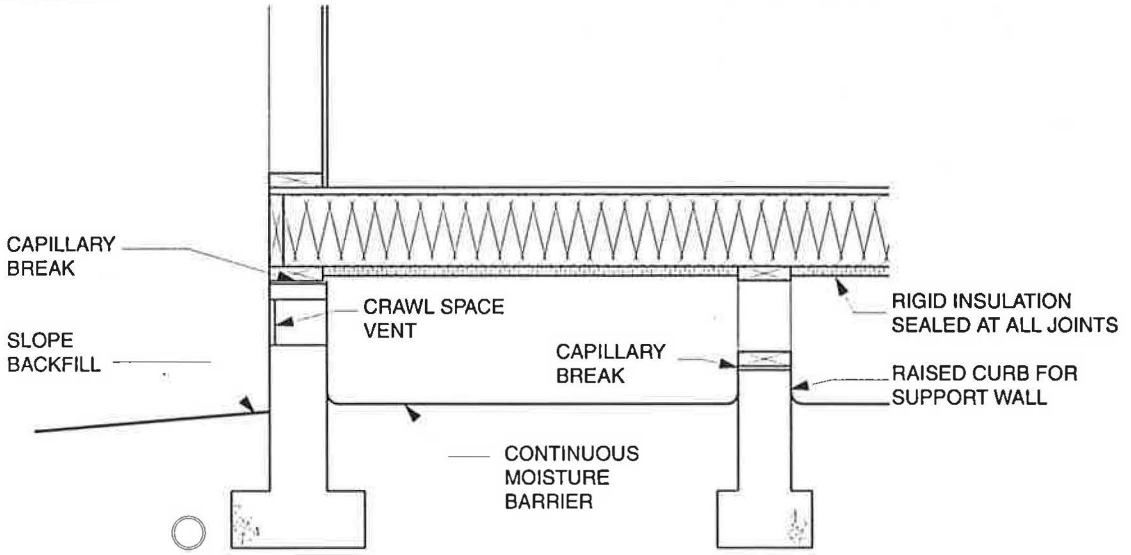


FIG.4 UNCONDITIONED CRAWL SPACE

- Use a coarse granular fill under slabs to provide a capillary break.
- Dampproof the inside of crawl space foundation walls to reduce moisture migration into the space.
- Dampproof the top of foundation walls to prevent the rise of capillary water from unprotected footings.
- Raise interior support walls resting on a crawl space floor above the slab level. If such walls are supported on the crawl space floor, the sill plate can absorb high amounts of moisture. When the walls sit on a curb above the skim coat level, they are better protected and the problem disappears.
- Provide a floor drain for the crawl space floor area.
- Allow drainage beneath the slab.

For conditioned crawl spaces, treat the construction like a shallow heated basement.

- Proper application of insulation materials to the interior wall surfaces of crawl spaces will reduce the moisture moved into the crawl space.
- Insulation on the interior of wall surfaces must be applied evenly to the top of the foundation wall above grade.
- Avoid creating cavities that are connected between the interior and exterior faces of the insulation, as this will generate convection currents that will move the moisture against the cold surface.

3. **For unconditioned crawl spaces:**

- The space should be well ventilated.
- Floor assembly above must be airtight with the appropriate insulation levels.
- Consider applying rigid impermeable insulation on the underside of the floor structure to protect the structure from wetting in summer. (Rigid insulation must be fire-rated if left exposed on the underside).
- Install a capillary break at the top of foundation walls, under the floor structure.
- Install a moisture barrier on the soil.

Insects

Insects are a concern in many areas, especially in mild humid climates. Warm, high humidity and moist conditions are usually ideal for insects. There is no universal method of dealing with insect problems, but addressing moisture issues will reduce them. Also consider local practices for dealing with insects common in the area.

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