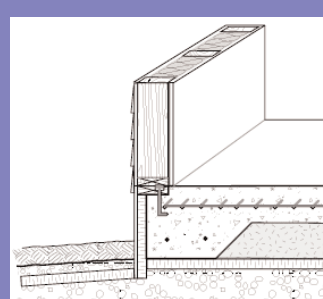
Insulated Slab-on-Grade Foundations



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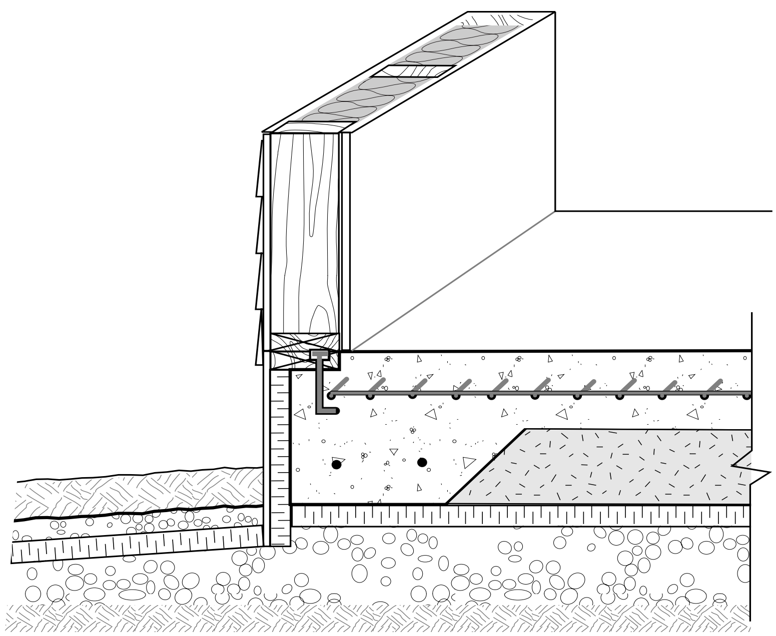

A Design Guide for Rural, Northern and First Nations Housing

ONTARIO FIRST NATIONS TECHNICAL SERVICES CORP.

First Nations (Alberta) Technical Services Advisory Group

CMHC SCHL

Credits

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Disclaimer

The booklet is solely intended for the purposes of slab-on-grade, frost-protected, shallow foundations subject to the limitations set out. The scope is not intended to encompass any other aspects of the house construction.

The design and the construction of the foundation is solely the responsibility of the builder/contractor. Consequently, we cannot accept liability for modifications to the design method or for use of the design method outside the stated limitations, or for designs not built according to Codes and good building practice. Furthermore, we cannot accept responsibility for material defects, specific site conditions or for the builder/contractor's judgment and as such, no warranty is expressed or implied.

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SECTION 1 Introduction

Purpose of this Guide

Slab-on-grade foundations are gaining increasing interest across Canada and hold considerable potential for rural, northern and First Nations housing as a means of constructing a lower cost, durable and energy-efficient foundation. When properly designed and constructed, slab-on-grade foundations minimize many of the problems commonly found with conventional foundation practices in northern and First Nations housing.

This booklet is intended to act as a concise guide, taking builders beyond interest in the subject to a point where they have design resources to be able to successfully construct a frost-protected, slab-on-grade foundation.

The guide is intended to give builders the knowledge and confidence to design and construct trouble-free foundations.

For design and site conditions that fall within the guidelines set out in this booklet, a frost-protected, slab-on-grade foundation can be designed and constructed using the information in this guide, without having to retain a professional engineer, except in extreme or non-typical circumstances.

A Brief History

In Canada, tradition and concerns about frost heave have led to the mistaken impression that good design practice requires that foundations must be constructed on footings located below the frost line. In the days before full basement construction, however, leaves, straw, seaweed and even snow were frequently placed next to exterior walls to protect foundations from temperature extremes. Modern frost protection methods are an extension of this practice—using rigid insulation to protect the foundation.

Modern frost-protected shallow foundations (FPSF) have been in common usage for more than 35 years. In Scandinavia, more than a million FPSF have been built with very successful results. Interestingly, the design guides used in these countries are largely based on Canadian research.

Many Canadian authorities have concluded that slab-on-grade foundations provide one of the most effective ways of improving the affordability and quality of housing in northern climates. The Ontario First Nations Technical Services Corporation (OFNTSC) and Canada Mortgage and Housing Corporation (CMHC) have prepared this booklet specifically to remove barriers to the use of frost-protected, shallow foundations in rural, northern and First Nations housing.

Benefits of Insulated Slab-on-Grade Foundations

A properly designed insulated, slab-on-grade foundation has been proven to provide trouble-free, comfortable construction for a variety of residential and non-residential buildings. The benefits of using such foundations include:

- reduced construction costs;
- reduced excavation costs;
- reduced use of materials (concrete, concrete block, fill, etc.);
- greater ease and speed of construction;
- reduced need to drain adjacent soils; and
- avoidance of problems related to moisture.

Many people question the concept of digging a large hole in the ground for a foundation. They liken the practice to that used by farmers to collect water for their livestock. Conventional foundation techniques—especially in northern communities—are prone to develop moisture problems. The action of frost, soil pressures and hydrostatic water pressures can all result in water leakage into conventional foundations. High moisture levels in these foundation systems are common and, in extreme conditions, can result in the premature deterioration of the building.

The concept behind a slab-on-grade foundation is premised on several principles:

- by maintaining the foundation at grade level, the potential for moisture-related problems is minimized;
- by eliminating the basement, the costs of heating an additional volume of air is eliminated; and
- by keeping the foundation at grade, problems relating to soil pressures are minimized.

Slab-on-grade construction has some inherent limitations relative to design:

- by eliminating the basement or crawl space, mechanical systems take up space on the house main floor;
- storage facilities must be integrated into the house design;
- the technique is less suitable in locations where access to ready-mix concrete is limited; and
- planning of services (phone, plumbing, etc.) must be accurately identified prior to placing of concrete.

Issues and Concerns

The most common technical concerns associated with slab-on-grade foundation construction in Canadian climates relate to the potential for frost heave and settlement leading to foundation cracks, movement of the structure, damage to finishes and structural problems. These problems can be expensive to repair.

With the placement of footings at or near grade, care is needed with respect to items such as:

- *structural issues*—foundations must bear on undisturbed soil, free of organic matter. The slab must be capable of transferring the building loads through to the bearing soils;
- *heat flow*—insulation levels and placement procedures must account for both occupant comfort as well as frost protection concerns;
- *air leakage*—the foundation system must be designed to avoid the entry of soil gases into the home; and
- *moisture*—foundations must be designed to restrict the entry of water and to prevent the entry of soil vapour into the building.

Traditional slab-on-grade designs have employed frost walls around the building perimeter. Insulated or frost-protected slab-on-grade foundations use insulation in place of soil to control heat loss and avoid freezing conditions next to and beneath the slab. Simply stated, 2" (50 mm) of insulation serves the same function as 4' (1,200 mm) of soil in protecting the footings.

Insulation is used to retain the heat immediately adjacent to the foundation, which comes from two sources:

- heat flowing from inside of the house to the soil beneath and beside the slab; and
- geothermal heat from the deep soil—heat stored in the earth below the frost level.

Design Principles

To understand the rationale behind insulated slab-on-grade design, it is important to understand the nature of heat flows affecting slab-on-grade construction.

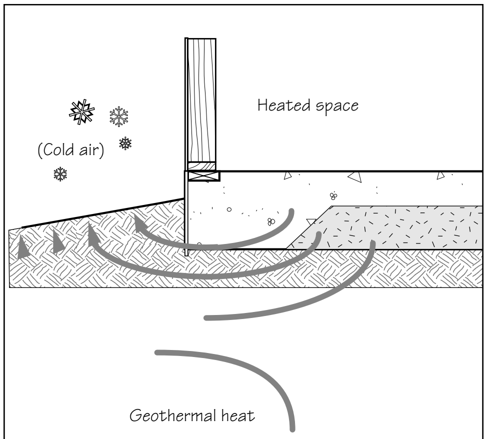
The most significant heat loss from the slab-on-grade occurs in the perimeter band of soil immediately adjacent to the building. Heat loss at corners is most pronounced because it occurs in two directions.

By strategically placing insulation in the ground, this heat loss can be used to keep the slab from freezing and heaving.

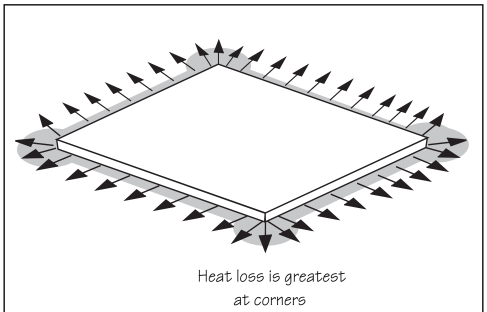
Horizontal insulation installed in "wings" sloping outward, around the perimeter of the slab, has the following effects:

- it extends the heat flow path;
- it controls heat loss; and
- it moves the line of frost penetration away from the slab.

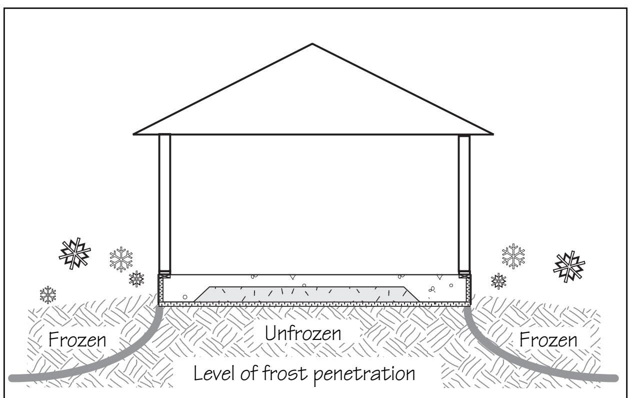
Proper detailing will also promote drainage and help keep structural elements warm and dry.



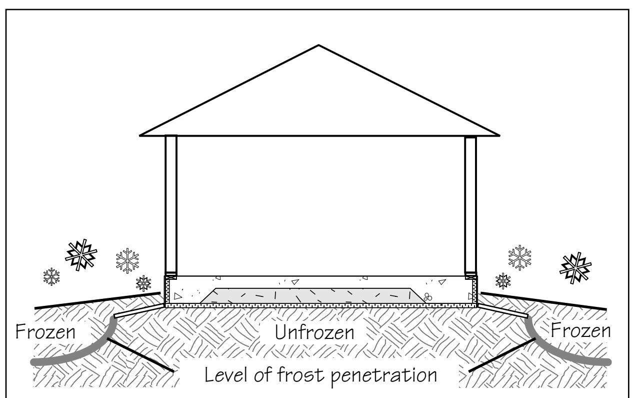
Heat Flows from Slab-on-Grade Foundations



Heat Flows from Perimeter of Slab



Frost Penetration from Typical Slab-on-Grade



Frost Penetration from Insulated Slab-on-Grade

SECTION 2 Design Limitations and Assumptions

The design method used in this booklet is intended to accommodate designs for most geographic regions in Canada. The following limitations to the method must be noted:

- The design method is intended for use on Part 9 residential buildings:
  - of two storeys or less;
  - with typical house floor loads.

- Construction will be in non-permafrost regions (i.e., regions having an average mean annual temperature greater than 32°F (0°C). Foundation design in permafrost usually includes strategies to keep the ground frozen rather than unfrozen.

- Slab design will be appropriate to the bearing capacity of soils and will take into account any unusual loading conditions.

It is assumed that such designs are only to be applied in the following ways:

- On heated buildings, it will not adequately protect buildings which are unheated for prolonged periods.

- On buildings completed, backfilled and heated before freezing weather occurs.

Elements above the foundation must comply with local Codes and/or the National Building Code.

Insulation in contact with soil as specified in the design must be either Type II, III, or IV.

Builders using the method should note that the insulation levels specified will probably be found to be adequate for floor comfort. The design method assumes the worst case for soil frost-susceptibility and as such, the specified insulation levels may be conservative in some cases.

Proper site grading is required, sloping the finished grade level away from the structure to direct surface water away from the foundation.

Adequate measures must also be taken to avoid damage to the slab insulation—both during construction and over the expected service life of the assembly—typically by covering the wing insulation with a minimum of 8" (200 mm) of backfill.

SECTION 3 Design Procedure

The design procedure specifies the thickness and width of the horizontal wing of insulation that is to be installed around the perimeter of the slab-on-grade. It assumes that the area under the slab as well as the slab edge are insulated to a minimum of R 10 (RSI 1.8). The thermal resistance and width of the perimeter insulation is specified based on the severity of the climate — as indicated by degree days below 18°C.

Step 1

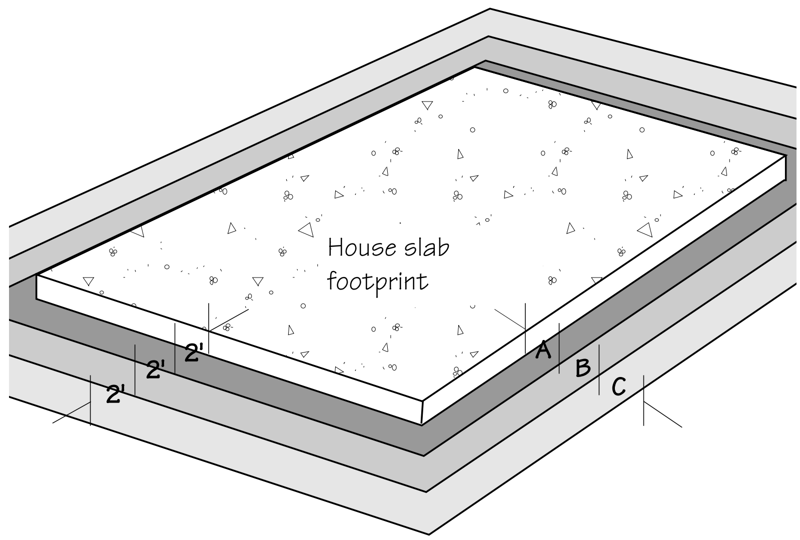
Select the closest location as listed in Table 1, or consult the Ontario Building Code for the degree day rating of your specific location. The rating provides an indication of the severity of the climatic conditions in the vicinity of the site.

City	Degree Days C
Barrie	4575
Big Trout Lake	7699
Brantford	4241
Brockville	4230
Chapleau	6214
Cornwall	4418
Dryden	6087
Gravenhurst	4911
Kenora	5938
Kingston	4251
London	4133
Moosenee	7011
North York	3999
North Bay	4990
Ottawa	4634
Peterborough	4411
Parry Sound	4730
Sudbury	5043
Sioux Lookout	6278
Toronto	3646
Thunder Bay	5673
Wawa	5756
Windsor	3622

Table 1:
Degree Day C (Below 18°C) by Location

Step 2

Consult Table 2 for the wing width and thickness for the insulation layer that is required to protect the footing. While in warmer parts of the province, only a 4' (1.2 m) wing will be required; in more severe climates, the width of the wing might need to extend out 6' (1.8 m) from the foundation perimeter.



Perimeter Foundation Zones

Degree Days Below 18°C	**Required R (RSI) Value of Insulation by Zone** Representing 2' (600 mm)		
	A	B	C
Less than 3800°C	10 (1.76)		
3800 – 6000°C	10 (1.76)	10 (1.76)	
More than 6000°C	10 (1.76)	10 (1.76)	5.0 (0.88)

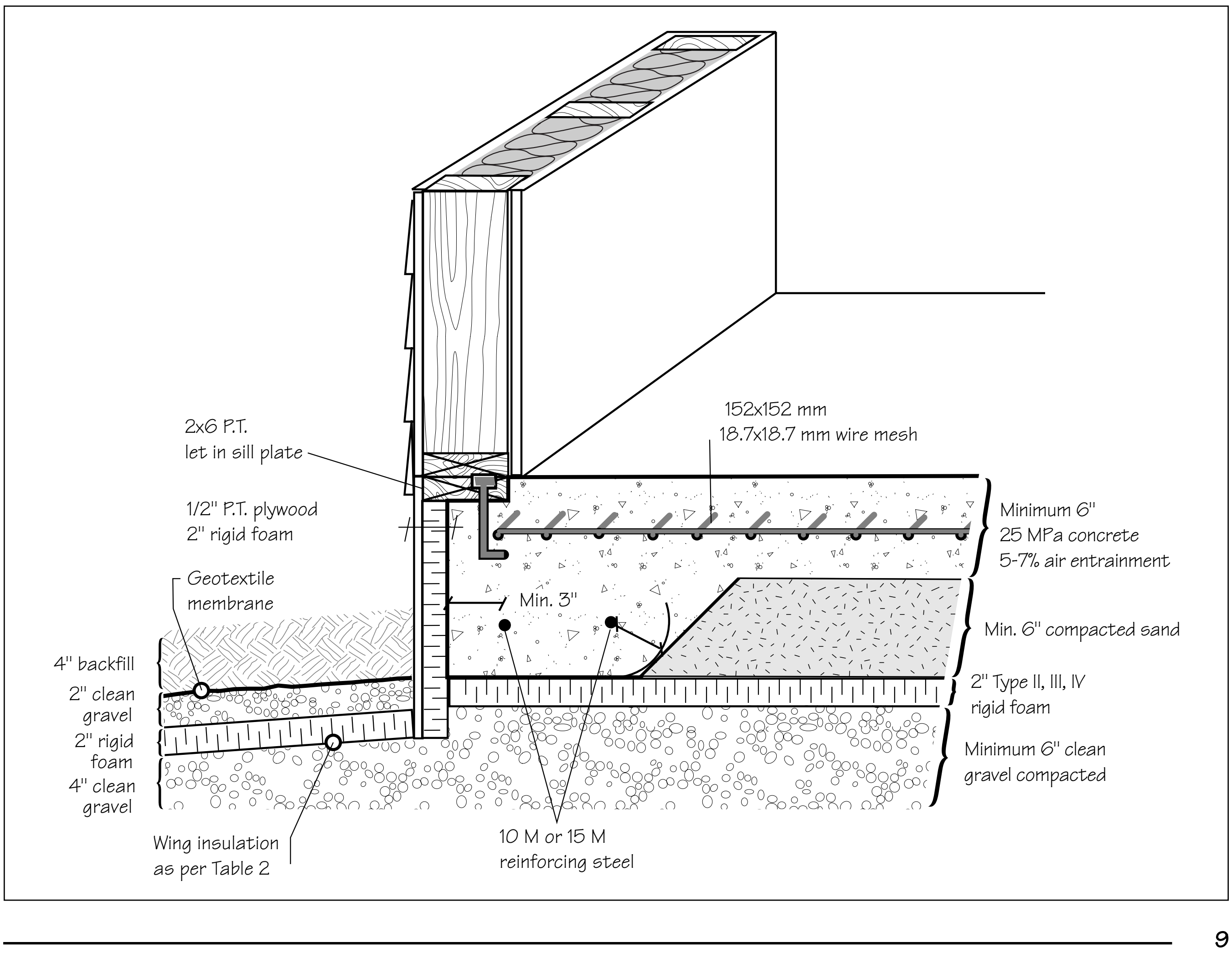
Table 2:
Determining Required Insulation

This design will produce a foundation with a typical cross section as shown below. Some important design considerations are assumed:

- The excavation is sloped to an outflow point (exterior drain or dry well) and lined with a minimum of 6" (150 mm) of free-draining granular material.
- The entire slab is insulated to a level of R 10 (RSI 1.8). Insulation in contact with the soil is Expanded Polystyrene Type II or III, or Extruded Polystyrene Type IV, meeting requirements of CGSB 51.20-M.

- A 6-mil polyethylene sheet is provided over top of the sub-slab insulation to meet soil gas control requirements of Building Codes.
- Wood formwork and plates cast into concrete are pressure-treated lumber.
- The concrete specified is a minimum of 25 MPa, with 5-7 per cent air entrainment.
- Where 25 MPa concrete is unavailable, welded wire mesh must be installed at the mid-point of the slab as reinforcing.

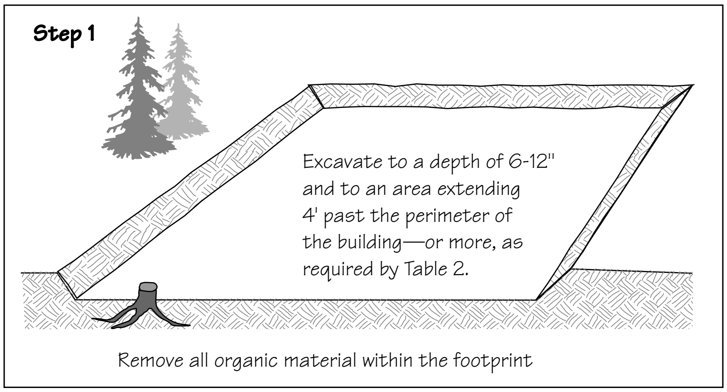
  Where required, wire mesh should be a minimum 6x6" (152x152 mm) welded wire mesh (and should be over-lapped a minimum of 8" (200 mm) at joints.
- All reinforcing steel (#10) placed in the concrete must be covered with a minimum of 3" (75 mm) of concrete (top, bottom and edges).
- *Good concrete curing practices are applied and saw-cut control joints are provided every 14-18' (4-5 m).*



SECTION 4 Construction Procedures

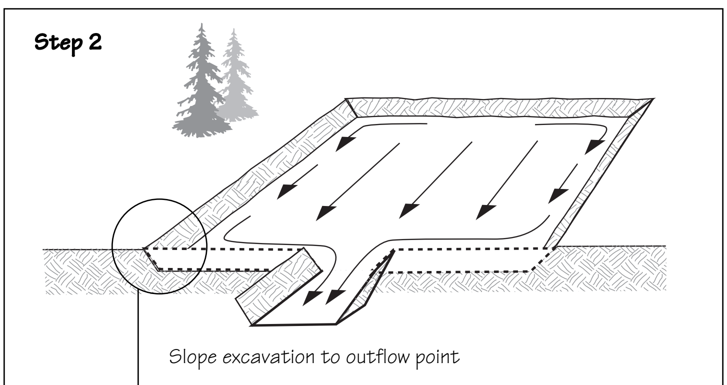
Having established the key variables associated with the design configuration, construction details must be considered.

The site work can proceed quickly and easily by means of the following steps.



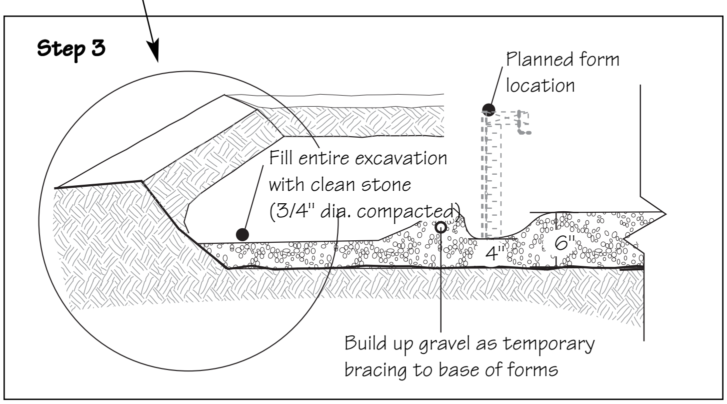
Step 1: Clear the Site and Level for Footings

Remove all organic material: topsoil, leaves, trees, roots, etc. This often requires excavation/scraping to a depth of 6-12" (150-200 mm). The area excavated should be large enough to accommodate the footprint of the building as well as the required width of the perimeter wing insulation surrounding the building. Trenching for services entrances should also be performed at this point.



Step 2: Slope Excavation to an Outflow Point

Level the subsoil, paying particular attention to maintaining undisturbed soil beneath the building. The excavation should be sloped to an outflow point or dry well located away from the building. Ensure that positive drainage is achieved. A slope of 1/4"/ft. (1:50) should be provided.

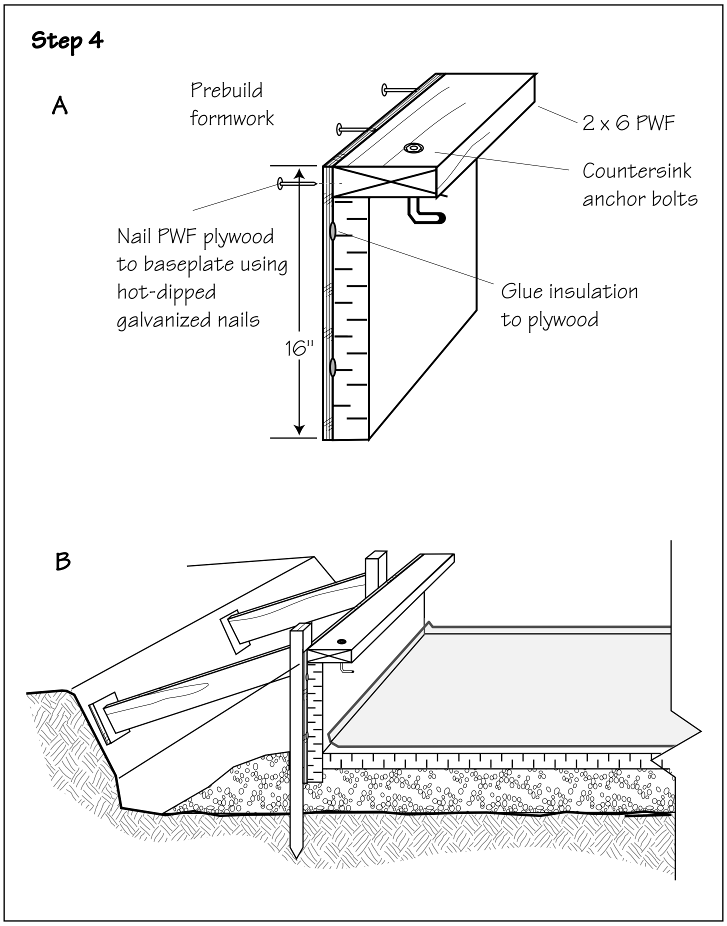


Step 3: Place Stone Drainage Bed

Use a minimum of 6" (150 mm) of 3/4" (19 mm) diameter clear stone under the proposed building footprint. Allow the gravel to extend 2' (600 mm) beyond the slab perimeter. Place and level the stone.

To avoid undermining the slab, do not use drainage tile or "O" pipe in the trench for additional drainage. Compact stone over top of trenches provided for services (water, waste and electrical) to ensure good bearing.

If constructing on sensitive clays or silty soils, install a sand filter or geotextile membrane to minimize disturbance of the soil, which can reduce bearing capacity.



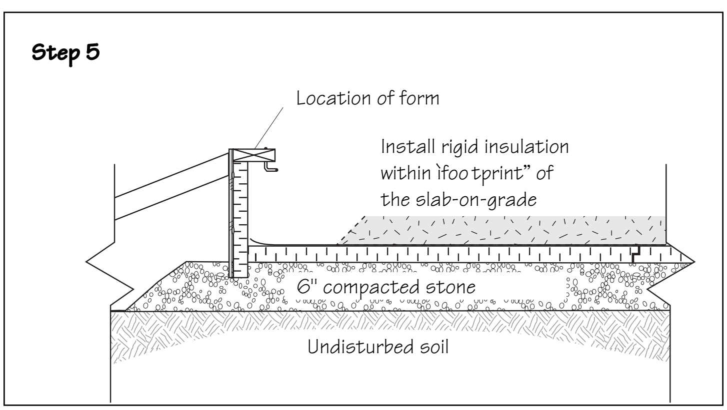
Step 4: Build and Erect Formwork

Stake out the perimeter of the building accounting for the thickness of the plywood forms and slab edge insulation. Drive rebar stakes through the gravel at the corners of the building to locate and support the formwork.

The slab edge insulation, pressure-treated plywood and wall baseplate can be constructed and used as formwork employing the following steps:

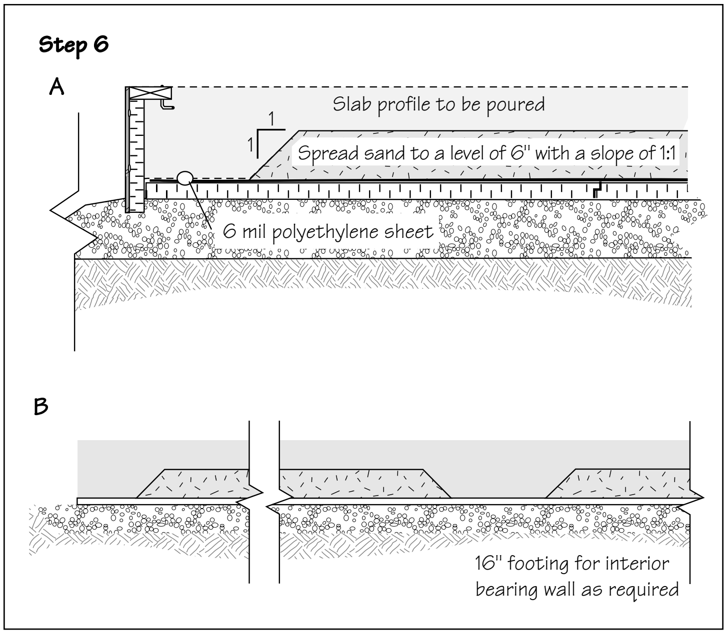
- Cut pressure-treated plywood into 16" (300 mm) strips.
- Pre-drill 1/2" (12.7 mm) holes for anchor bolts through a 2x6 (38x140 mm) treated plate at 10' (2.4 m) on centre. The holes should be located at 1½" (38 mm) from the inside edge of the plate.
- Nail the baseplate to the top edge of the plywood using hot-dipped galvanized nails.
- Fasten the perimeter slab insulation to the inside edge of the plywood.
- Brace the form. Wood stakes can be used as midpoint supports.
- Attach the completed form to the layout stakes on three sides of the perimeter, leaving one side open for ease of movement of materials. Trench the forms into the drainage layer to depth of 4" (100 mm).
- Insert the 1/2" (12.7 mm) anchor bolts.

Brace the formwork to prevent kick-out during the pour. Remember, concrete is heavy and will exert significant pressures on the forms.



Step 5: Place Insulation Layer

Place the layer of rigid polystyrene insulation (R 10 (RSI 1.76)) over the levelled stone drainage bed inside of the forms. Ensure joints in the rigid board insulation are tight fitting. Fit the insulation tightly around service entrances. A shiplap joint configuration will provide optimum coverage along the length of the sheets. Make certain that the insulation is in full contact with the granular material.



Note re: Mechanical Services

Slab-on-grade construction requires careful layout and installation of services to ensure that they extend from the slab in the correct locations. Service entrances must be adequately braced to ensure they are not dislocated during the concrete pour.

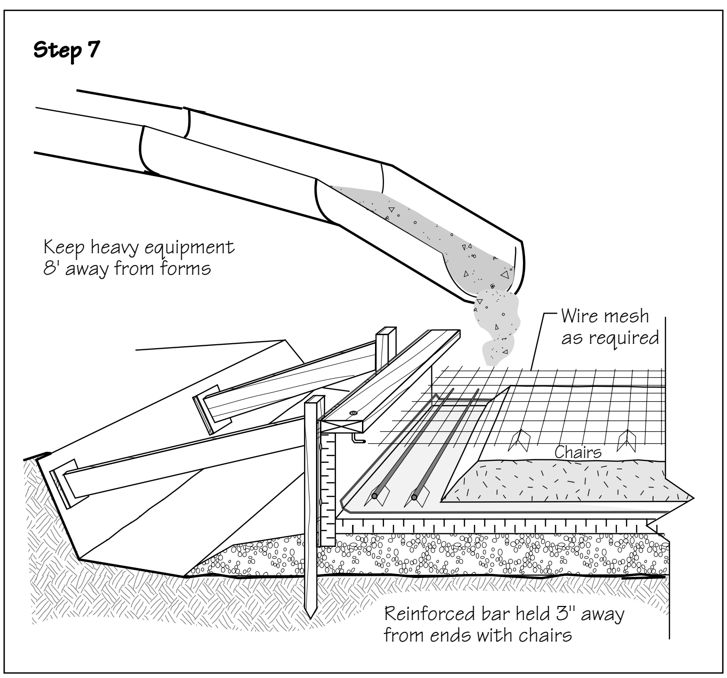
Step 6: Install Polyethylene and Sand

Lay a 6 mil polyethylene sheet over top of the insulation layer inside of the perimeter of the foundation. Joints in the polyethylene should be overlapped a minimum of 12" (300 mm).

Place a 6" (150 mm) layer of sand over the centre area of the excavation. Spread, level and compact the sand so that it slopes to the base of the perimeter footing at a 1:1 slope (45-degree angle).

Where the house design requires an interior bearing wall to carry roof or second floor loads, the slab must be thickened to provide additional bearing support. When spreading the sand, allow for a 16" (400 mm) width footing to be centred under the bearing wall. Where the load is carried on posts, a 36" (900 mm) diameter footing is required. In both cases, the concrete should be the same thickness as that at the perimeter footing.

Install the fourth and final section of the formwork and brace the form as in Step 4.

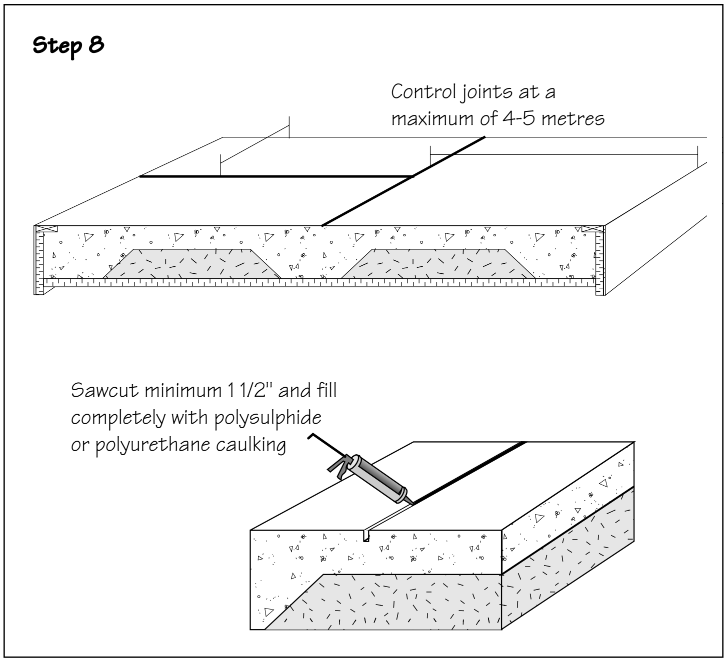


Step 7: Place Reinforcing Steel, Wire Mesh (as required) and Pour Concrete

Footing rebar should be placed so that 3" (75 mm) of concrete coverage is attained. The steel can be temporarily supported at the required position using either stone or “chairs”fabricated from folded wire mesh.

Where required, install wire mesh using chairs to maintain its position. Wire mesh can also be installed and worked into the concrete during placement of the concrete, 3" (75 mm) coverage is required.

The slab-on-grade must be at least 6" (150 mm) thick. Place the concrete carefully to minimize segregation of the aggregates. Never add water on the site as this will result in weaker concrete and increases the potential for shrinkage cracking.



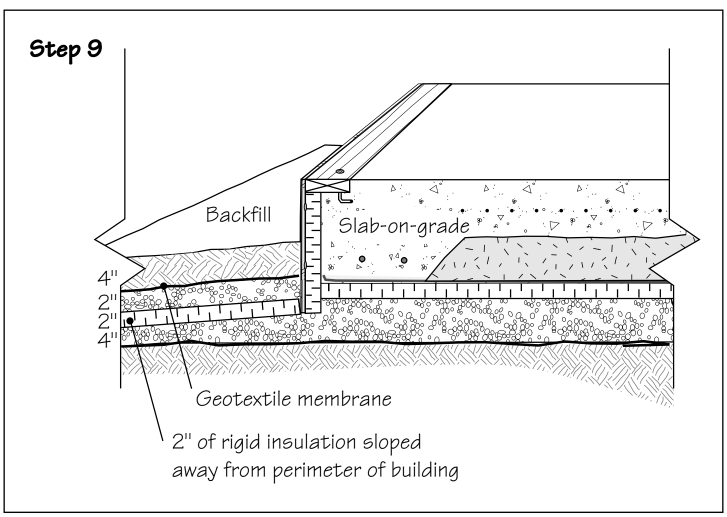
Step 8: Finish Concrete

Do not finish the concrete when bleed water is present. This will result in fines rising to the top of the slab, increasing the likelihood of spalling of the finish.

Control joints are required to minimize cracking of larger slabs. Sawcut 6-16 hours after placement of the slab. The depth of the cuts should be 1/4 of the thickness of the slab—approximately 1½" (38 mm). Control joints should be located at 14-18' (4-5 m), ideally under partition wall locations. Weaker aggregates in the mix (i.e., crushed limestone) dictate reduced spacing. Stronger aggregates (crushed granite) allow increased spacing of control joints.

Concrete should be kept continuously moist for at least three days after placement. Cover the slab with tarps or polyethylene to reduce evaporation. In freezing weather, the concrete should also be kept warm using either insulating blankets or straw.

Finish the control joints and penetrations in the slab with a gun-grade polysulphide or polyurethane caulking.



Step 9: Insulate Horizontal Trench Adjacent to the Building and Backfill

Remove the form stakes and bracing. Complete drainage layer and install the horizontal wing insulation around the perimeter of the building as required by the design. Ensure that there is a slope away from the building. Insulation panels should be butted tightly together. Shiplap edge insulation may be used to facilitate this.

Cover the insulation with a minimum of 2" (50 mm) of gravel, and cover with a geotextile membrane to minimize soil migration into the drainage layer. Backfill with a minimum of 4" (100 mm) of soil for ballast and protection. Ensure 8" (200 mm) clearance from the final grade to siding materials. Ensure that when completed, the house is equipped with eavestrough, downspouts and splashblocks to minimize splashing and ponding of water against the foundation walls.

SECTION 5 References

For further information on specific topics covered in this booklet, consult the following references:

1. *National Building Code of Canada*, National Research Council of Canada, 1995.

2. *Design Guide for Frost-Protected Shallow Foundations*, National Association of Home Builders Research Centre, NAHB, 1995.

3. *Design of Insulated Foundations*, Robinsky, Eli. I. et al, Journal of the Soil Mechanics and Foundation Division, ASCE Vol. 99, No. SM9, Proc. Paper 10009, September, 1973, pp. 649-667.

4. *Slab-on-Grade Foundations for Heated Buildings*, A521.111 Part 1 Building Research Design Sheets, Norwegian Building Research Institute, Oslo Norway, Spring 1986.